EXHIBIT A

US005528222A

United States Patent [19]

Moskowitz et al.

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[45] Date of Patent: Jun. 18, 1996

[54] **RADIO FREQUENCY CIRCUIT AND MEMORY IN THIN FLEXIBLE PACKAGE**

[75] Inventors: **Paul A. Moskowitz**, Yorktown Heights; **Michael J. Brady**, Brewster; **Paul W. Coteus**, Yorktown Heights, all of N.Y.

[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **303,977**

[22] Filed: **Sep. 9, 1994**

[51] Int. Cl.[6] **H04Q 1/02**

[52] U.S. Cl. **340/572**; 29/825; 29/829; 29/836; 340/825.3; 340/825.34; 340/825.54

[58] Field of Search 340/572, 825.34, 340/825.3, 825.54; 29/836, 829, 825

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Primary Examiner—Glen Swann
Attorney, Agent, or Firm—Louis J. Percello

[57] **ABSTRACT**

A novel thin and flexible radio frequency (RF) tag has a semiconductor circuit with logic, memory, and a radio frequency circuits, connected to an antenna with all interconnections placed on a single plane of wiring without crossovers. The elements of the package (substrate, antenna, and laminated covers) are flexible. The elements of the package are all thin. The tag is thin and flexible, enabling a unique range of applications including: RF ID tagging of credit cards, passports, admission tickets, and postage stamps.

29 Claims, 10 Drawing Sheets

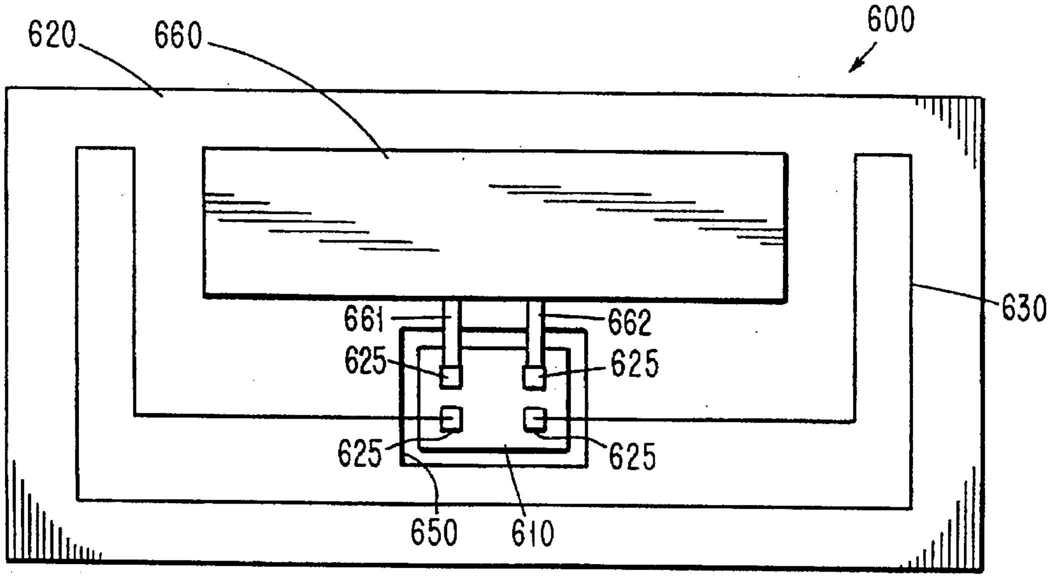


FIG. 1A
PRIOR ART

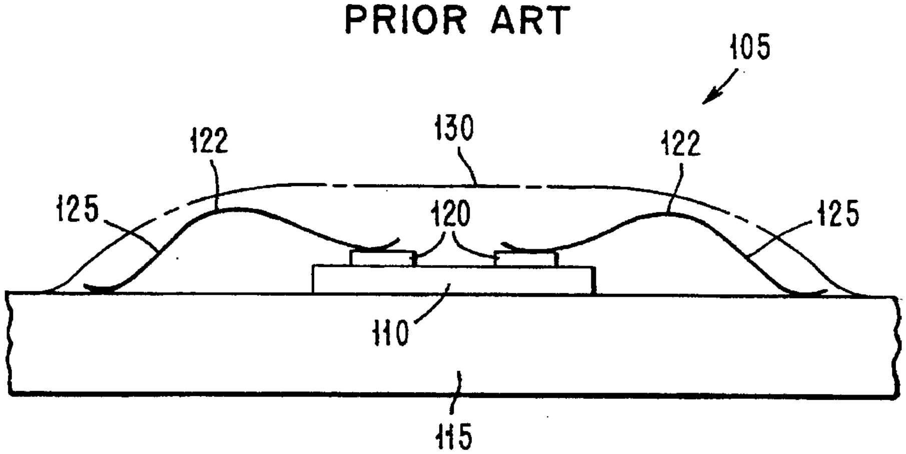


FIG. 1B
PRIOR ART

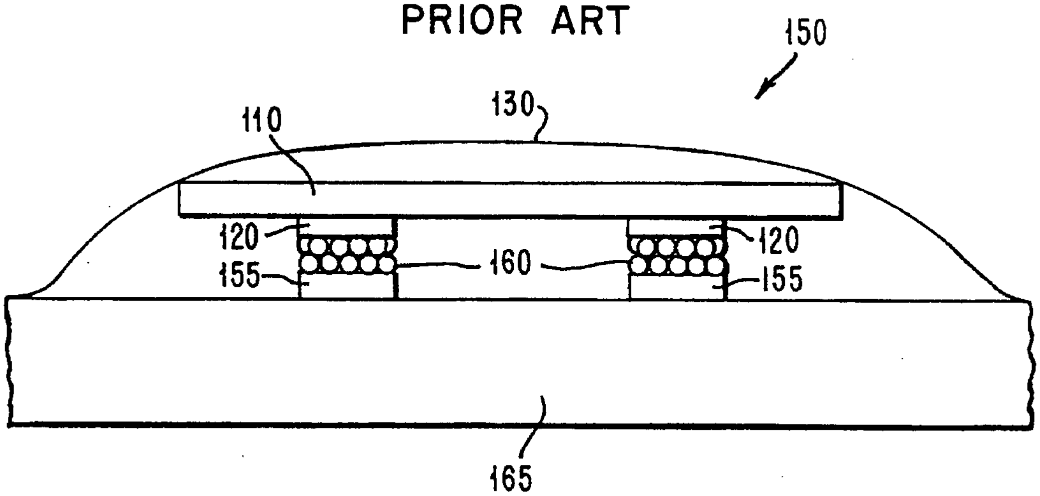


FIG. 2

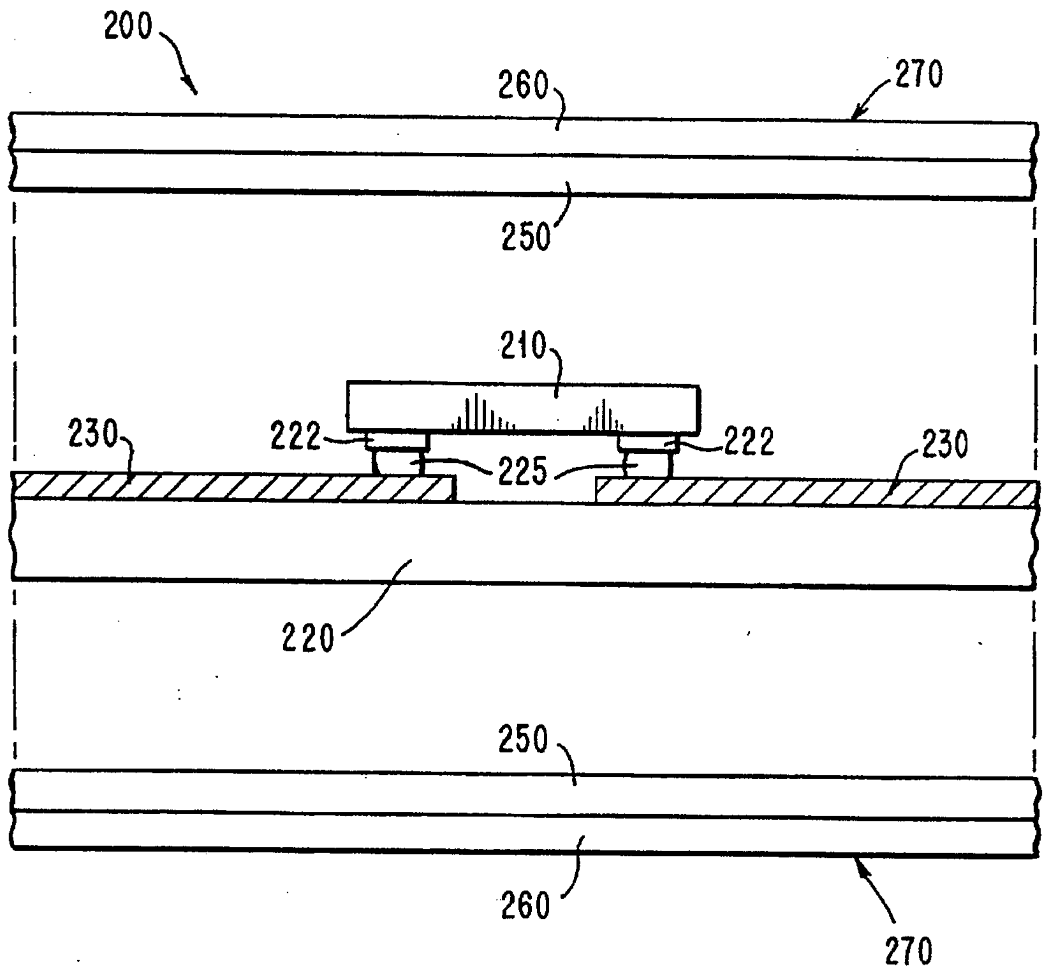


FIG. 3

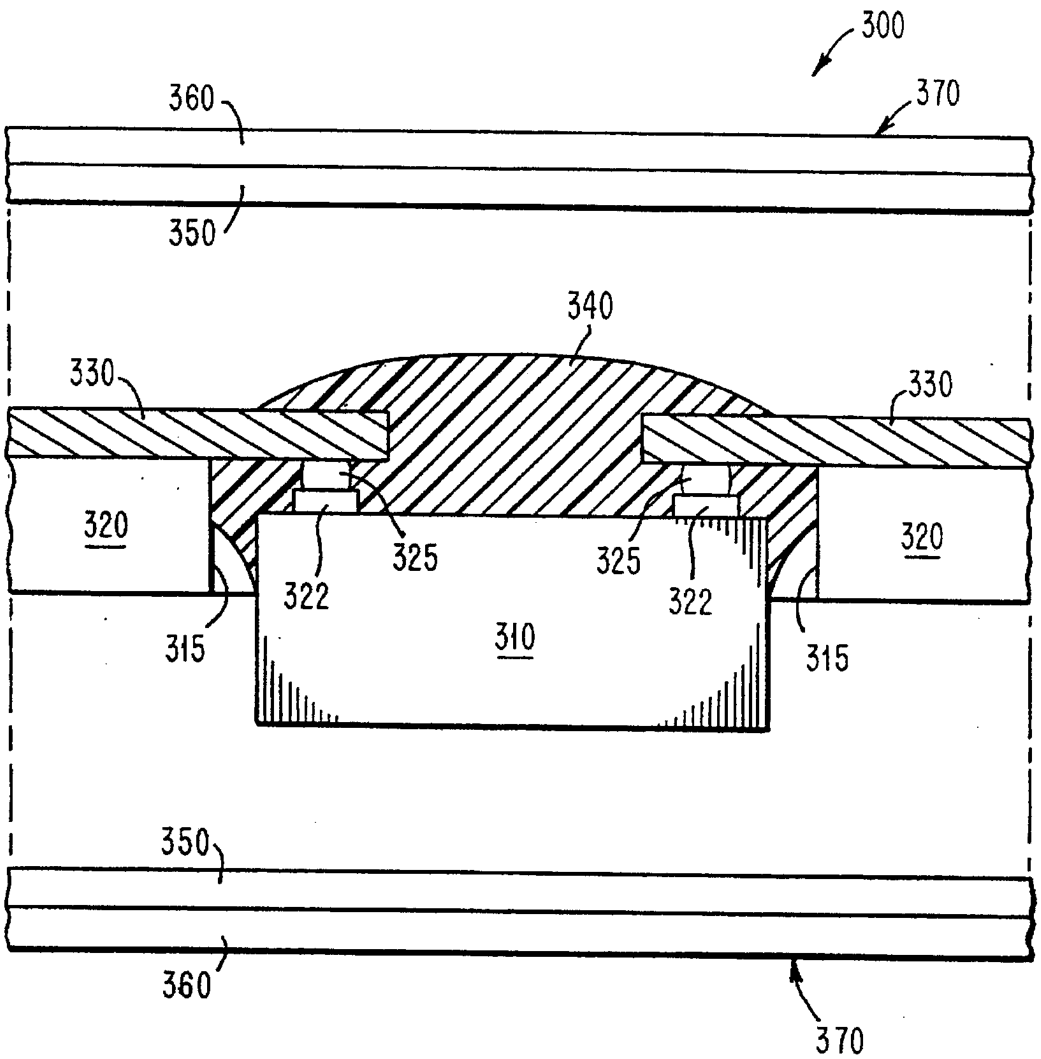
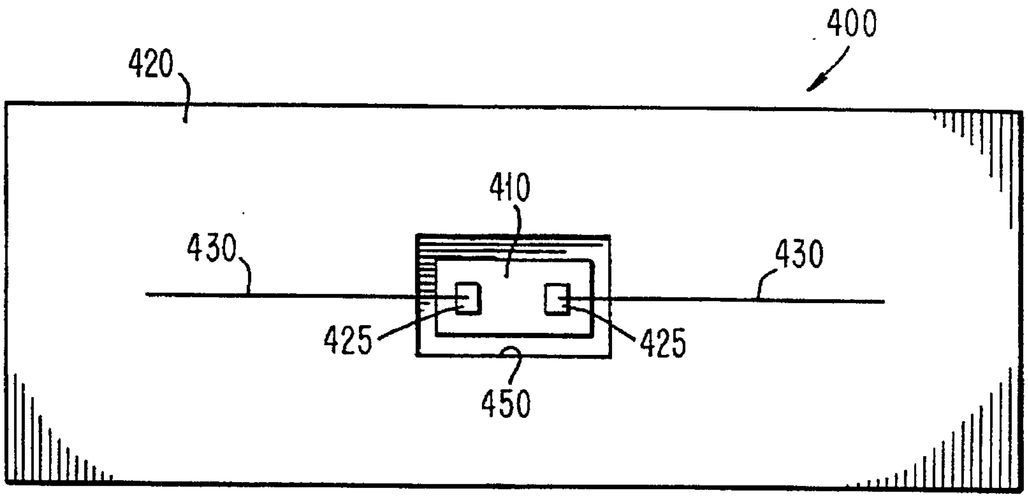
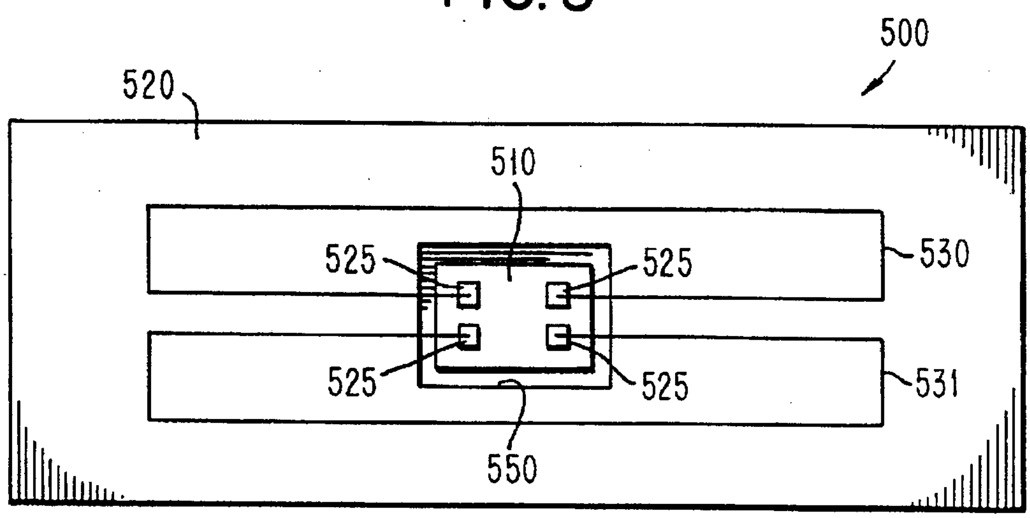

300
360
370
350
340
330
330
320
320
325
325
322
322
315
315
310
350
360
370

FIG. 4



400
420
410
430
430
425
425
450

FIG. 5



500
520
510
525
525
530
525
525
531
550

FIG.6

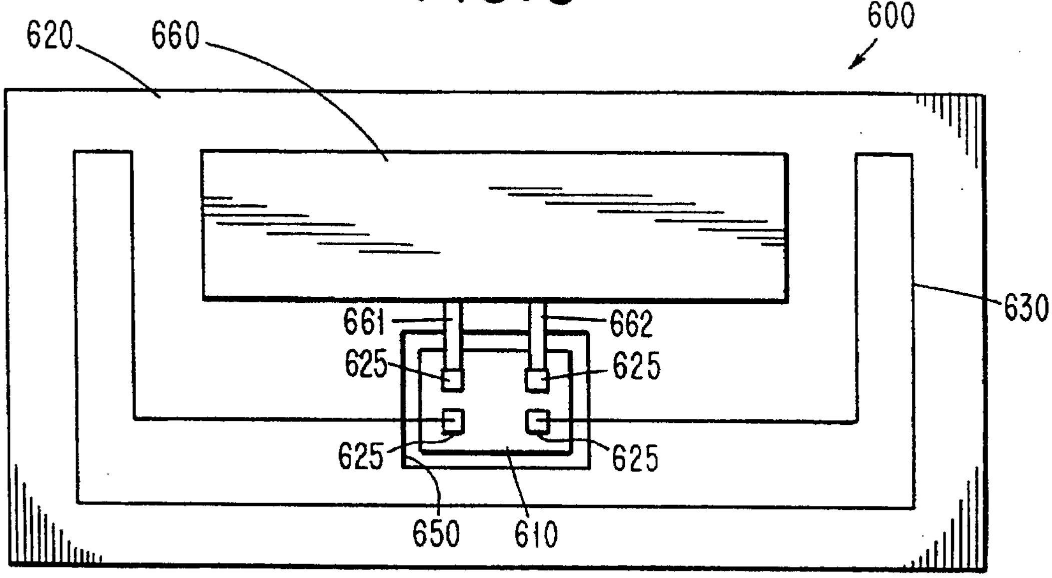


FIG.7A PRIOR ART

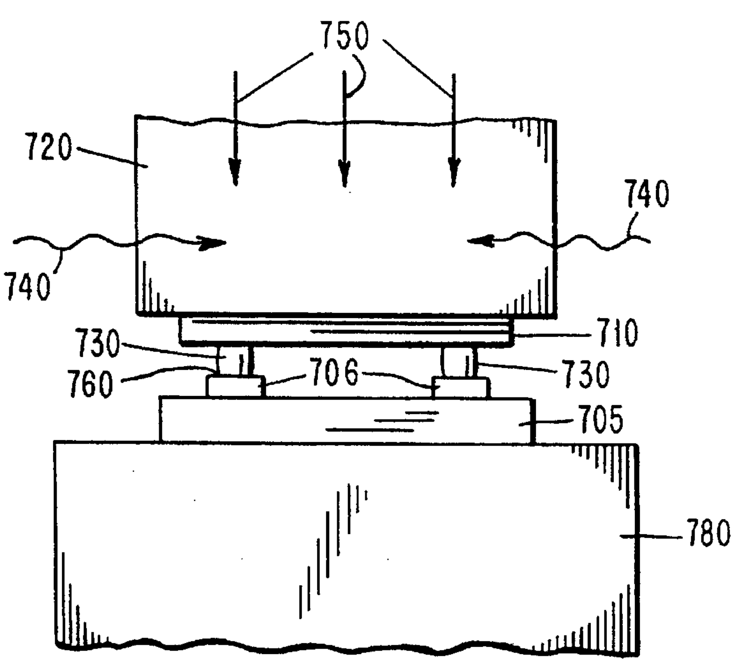


FIG. 7B
PRIOR ART

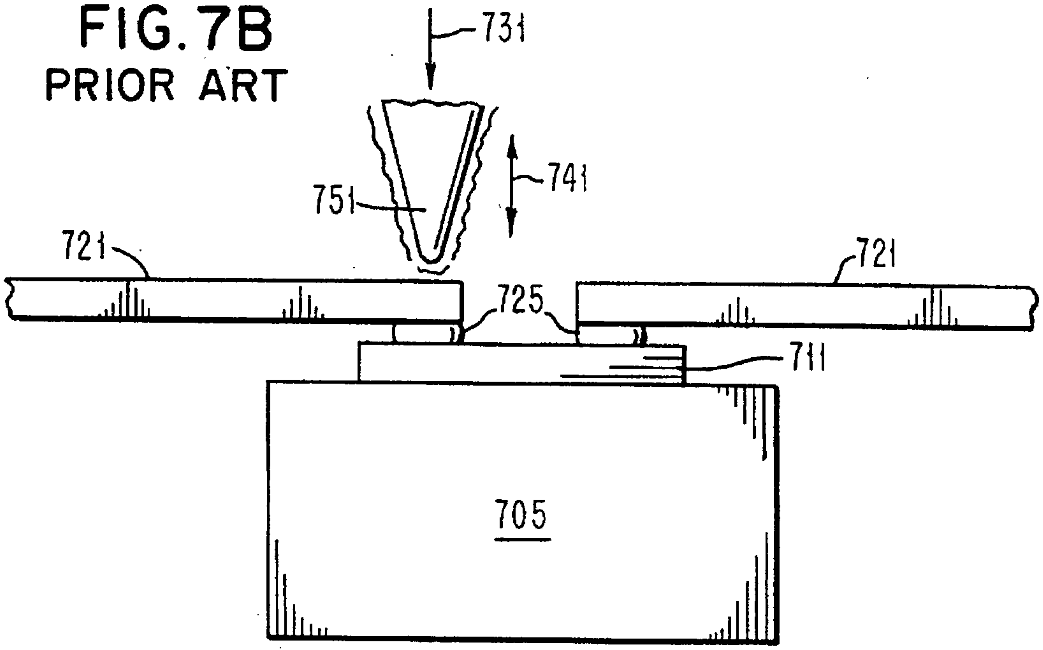


FIG. 7C
PRIOR ART

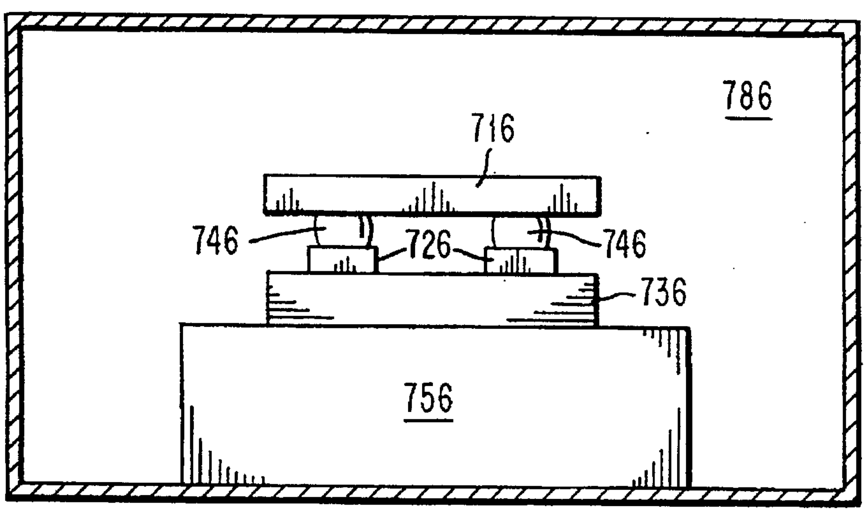


FIG. 7D
PRIOR ART

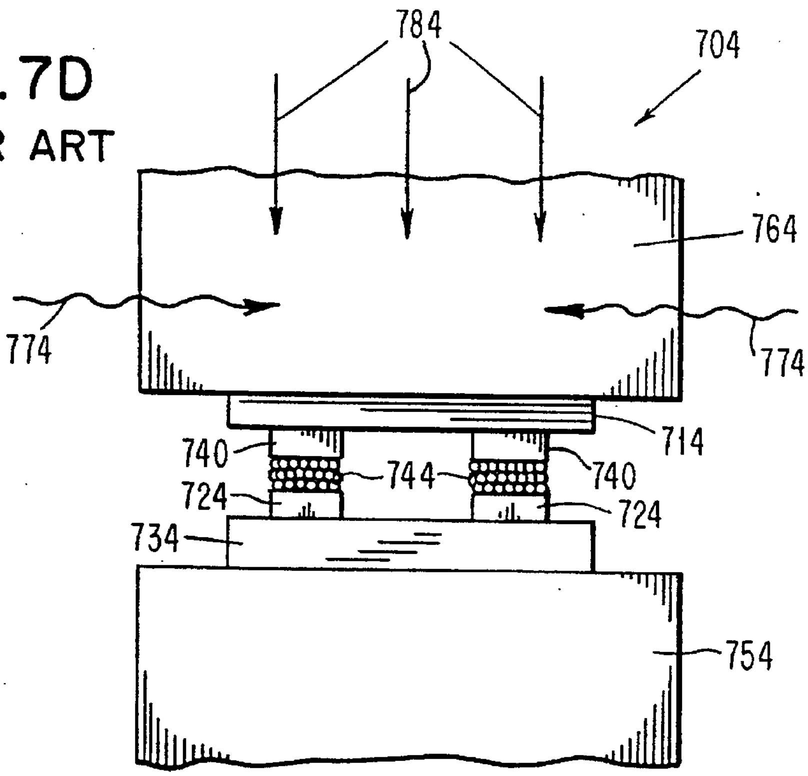


FIG. 7E
PRIOR ART

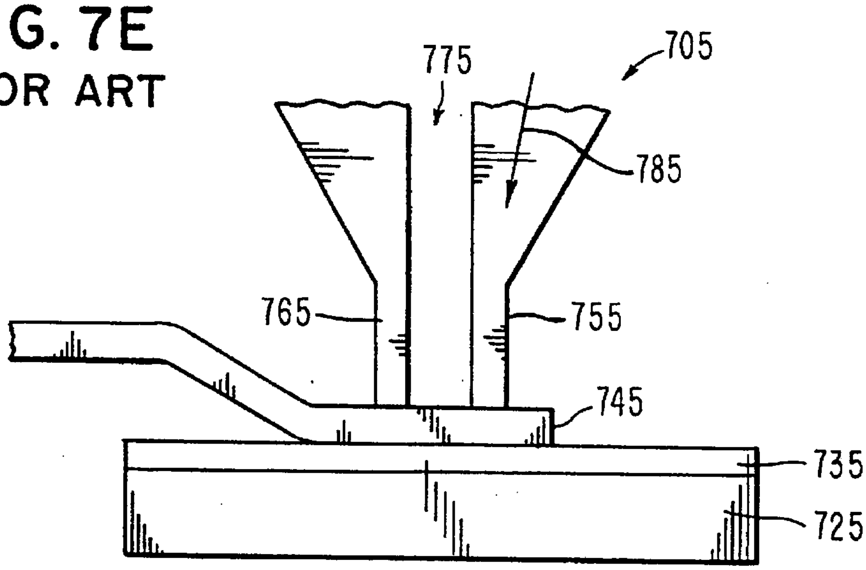


FIG. 8

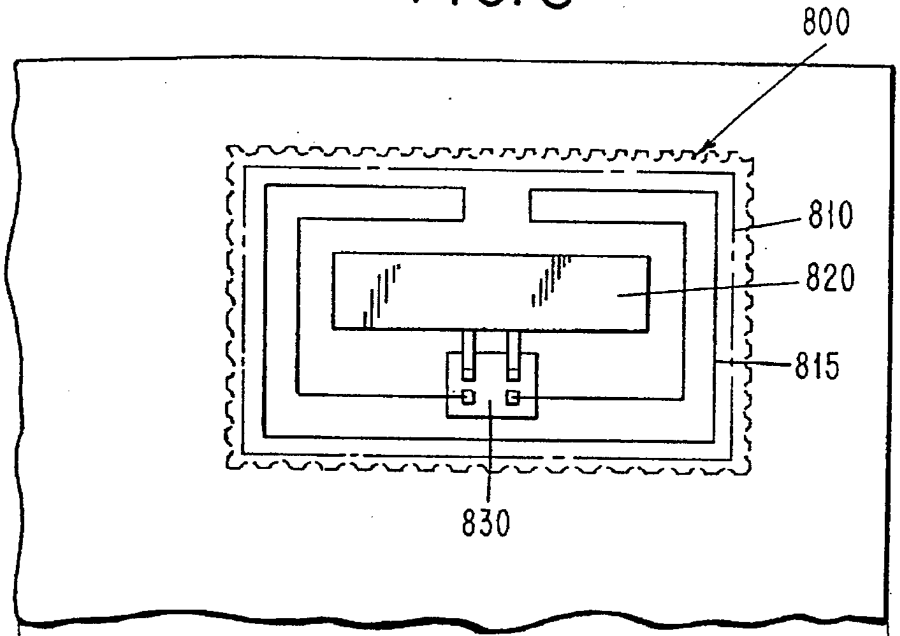


FIG. 8A

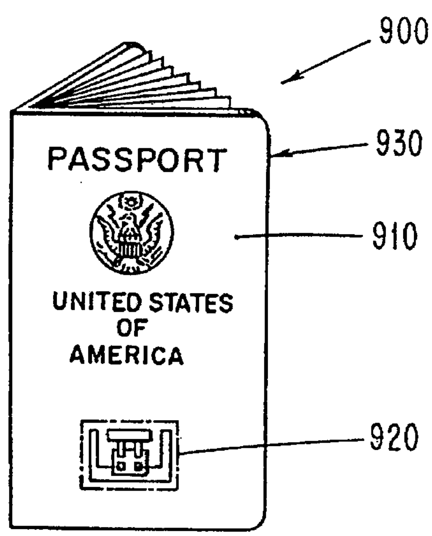


FIG. 9

FIG. 10

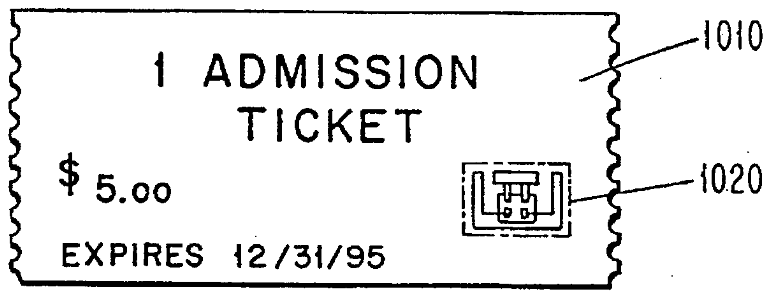

1 ADMISSION
TICKET
$ 5.00
EXPIRES 12/31/95
1010
1020

FIG. 11

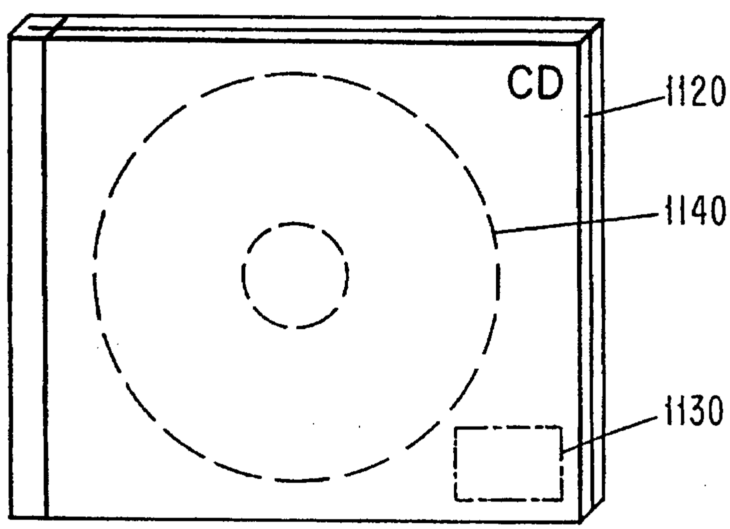

CD
1120
1140
1130

FIG. 12

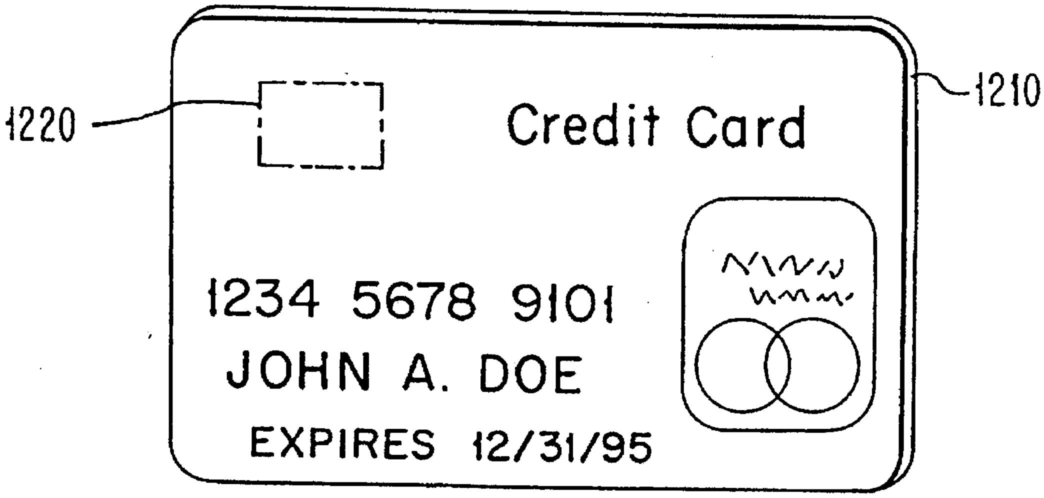
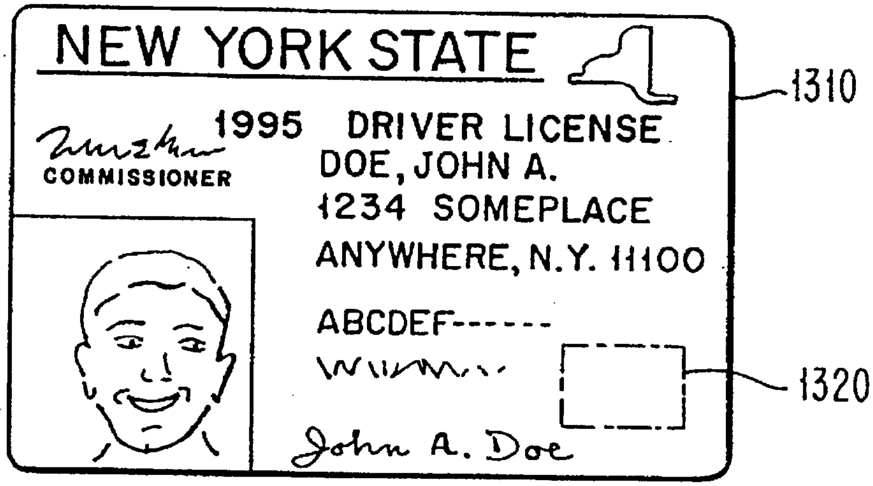

1220
Credit Card
1210
1234 5678 9101
JOHN A. DOE
EXPIRES 12/31/95

FIG. 13


NEW YORK STATE
1310
1995 DRIVER LICENSE
COMMISSIONER
DOE, JOHN A.
1234 SOMEPLACE
ANYWHERE, N.Y. 11100
ABCDEF------
1320
John A. Doe

RADIO FREQUENCY CIRCUIT AND MEMORY IN THIN FLEXIBLE PACKAGE

FIELD OF THE INVENTION

This invention relates to a radio frequency circuit and memory in a thin flexible package. More specifically, the invention relates to a thin flexible radio frequency circuit used as a radio frequency tag.

BACKGROUND OF THE INVENTION

Radio Frequency Identification (RF ID) is just one of many identification technologies for identifying objects. The heart of the RF ID system lies in an information carrying tag. The tag functions in response to a coded RF signal received from a base station. Typically, the tag reflects the incident RF carrier back to the base station. Information is transferred as the reflected signal is modulated by the tag according to its programmed information protocol.

The tag consists of a semiconductor chip having RF circuits, logic, and memory. The tag also has an antenna, often a collection of discrete components, capacitors and diodes, for example, a battery in the case of active tags, a substrate for mounting the components, interconnections between components, and a means of physical enclosure. One variety of tag, passive tags, has no battery. They derive their energy from the RF signal used to interrogate the tag. In general, RF ID tags are manufactured by mounting the individual elements to a circuit card. This is done by using either short wire bond connections or soldered connections between the board and the circuit elements: chip, capacitors, diodes, antenna. The circuit card may be of epoxy-fiberglass composition or ceramic. The antennas are generally loops of wire soldered to the circuit card or consist of metal etched or plated on a circuit card. The whole assembly may be enclosed in a plastic box or molded into a three dimensional plastic package.

While the application of RF ID technology is not as widespread as other ID technologies, bar code for example, RF ID is on its way to becoming a pervasive technology in some areas, notably vehicle identification.

Growth in RF ID has been inhibited by the high cost of tags, the bulkiness of most of the tags, and problems of tag sensitivity and range. A typical tag costs in the $5 to $10 range.

Companies have focused on niche applications. Some prior art is used to identify railway boxcars. These tags tend to be quite large and are made of discrete components on circuit boards mounted in solid, non-flexible casings. RF tags are now used in the automatic toll industry, e.g. on thruway and bridge tolls. RF tags are being tested for uses as contactless fare cards for buses. Employee identification badges and security badges have been produced. Animal identification tags are also commercially available as are RF ID systems for tracking components in manufacturing processes.

Tags exist that have the-length and width of a standard credit card. However, these cards typically are over 2.5 mm thick and have a non-flexible casing. Tags also exist that have a credit card size length and width but with bumps where circuit is placed that causes them to be too thick to fit in card reader machinery

While some electronic article surveillance (EAS), e.g. antitheft devices, are thin (0.3 mm) they typically contain limited amounts, (i.e., only one bit) of information. Some of

these devices can be turned off once but cannot be reactivated.

FIG. 1A shows one prior art structure of a radio frequency tag **105**. The tag **105** has a chip **110** mounted on a substrate **115**. The chip **110** has contacts **120** that are connected to circuitry on the substrate **115** by wire bonds **125**. An encapsulation material **130** covers the chip for environmental protection. The thickness of this tag **105** is determined by the combined thicknesses of the chip components. Typically, substrates in these tags are at least 10 mils, 0.25 mm, in thickness, the chip **110** along with the high loop **122** of the bond vary from 20 to 40 mils, 0.5 to 1 mm, in thickness and the encapsulation **130** is about 10 mils, 0.25 mm in thickness. As a result, tags **105** of this structure vary from a minimum of 40 to 60 mils, 1 to 1.5 mm, in thickness. This structure is too thick for many potential tag applications.

FIG. 1B shows another prior art structure **150** showing a chip **110** with the chip contacts **120** connected to circuitry contacts **155** with conducting adhesive **160**. The substrate **165** of this structure **150** is typically made as a FR4/printed circuit (thickness 40 to 60 mils, 1 to 1.5 mm) or flexible substrate (10 mils,0.25 mm). The chip **110** and adhesive **160** add another 20 to 40 mils, 0.5 to 1 mm, to the thickness and the encapsulation **130** adds still another 10 to 20, 0.25 to 0.5 mm mils in structure **150** thickness. This structure therefore can vary in thickness from 80 to 130 mils, 2 to 3.5 mm, making it thicker than the structure in FIG. 1A.

Other thick structures are known in the art. These include quad flat pak (QFP) and/or small outline pak (SOP) as components. Structures made with these components are at least 1 mm thick and usually 2 to 3 mm thick.

PROBLEMS WITH THE PRIOR ART

Prior art teaches that there is a long felt need to manufacture thin RF ID tags on flexible substrates. However, while the goal of a thin flexible tag is desired, the prior art has failed to reach the goal. One prior art reference discloses a tag that is 1.5 to 2.0 mm thick. This tag thickness limits the applications of this tag. For example, it is far thicker than the International Organization for Standardization (ISO) standard credit card thickness of 0.76 mm and therefore could not be used in a credit card to be inserted into a credit card reader.

The prior art has failed to produce a thin tag because: care is not been taken to make each of the elements thin; elements are stacked one upon the next; and the antenna and connecting conductors require more than one plane of electrical wiring, ie. the designs use cross-overs for completing interconnections. As elements are stacked and layers are added the package grows thicker and flexibility is lost.

Another prior art reference discloses a package with a total thickness of 0.8 mm. This is still greater than the ISO standard credit card thickness of 0.76 mm. Furthermore, while thin elements are disclosed, no care is taken to use flexible materials throughout. The components are mounted on a hard circuit card and encapsulated in plastic. (Hard means can not be torn easily by hand.) The result a is rigid package. The prior art has not shown the use of thin flexible laminate covering materials for the packages. The results are that the packages are thick, and inflexible.

OBJECTS OF THE INVENTION

An object of this invention is an improved thin radio frequency tagging apparatus.

An object of the invention is a flexible radio frequency tag apparatus with a thin flexible protective lamination.

An object of the invention is a flexible radio frequency tag apparatus that may fit within the thickness limit of an ISO standard credit card, a passport cover, a postage stamp, an anti-theft device, or an admission ticket.

SUMMARY OF THE INVENTION

The present invention is a novel radio frequency (RF) tag that comprises a semiconductor circuit that has logic, memory, and radio frequency circuits. The semiconductor is mounted on a substrate and is capable of receiving a RF signal through an antenna that is electrically connected to the semiconductor through connections on the semiconductor. The present invention is a novel structure of a radio frequency tag design that is thin and flexible. The tag has the antenna and all interconnections placed on a single plane of wiring without crossovers. The elements of the package are placed adjacent to one another, i.e., they are not stacked. Elements of the package, the substrate, antenna, and laminated covers, are flexible. The elements are all thin such that the total package thickness including covers does not exceed that of an ISO standard credit card. The resulting tag package, comprised of thin, flexible components arranged and connected in a novel way, is also thin and flexible. Accordingly, this enables a novel range of applications that include: RF ID tagging of credit cards, passports, admission tickets, and postage stamps.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**, comprising FIGS. **1A** and **1B**, is a drawing showing the cross section view of two typical embodiments in the prior art.

FIG. **2** is drawing showing a cross section of one preferred embodiment of the present thin RF ID tag.

FIG. **3** is drawing showing a cross section of one preferred embodiment of the present thin RF ID tag with an aperture in the substrate.

FIG. **4** is a top view of the thin tag showing a dipole antenna.

FIG. **5** is a top view of a thin tag having more than one folded dipole antennas.

FIG. **6** is a top view of a thin tag having a battery included in the circuit.

FIG. **7** comprises FIGS. **7A–7E** which are cross sections of prior art chip bonds to substrates by means of thermo-compression bonding (FIG. **7A**), ultrasonic bonding (FIG. **7B**), C4 solder bonding (FIG. **7C**), conducting adhesive bonding (FIG. **7D**), and spot welding (FIG. **7E**).

FIG. **8** shows a thin tag used as a postage stamp.

FIG. **8A** shows a thin tag enclosed in a parcel membrane or in the wall of an envelope.

FIG. **9** shows a thin tag placed in the cover of a passport using a resonant loop antenna.

FIG. **10** shows a thin tag used on an admission ticket.

FIG. **11** shows a thin tag used as an antitheft device.

FIG. **12** shows a thin tag placed inside a credit card.

FIG. **13** shows a thin tag placed inside a license.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **2** shows a side view of a novel RF ID tag **200**. The chip **210** is located on a flexible substrate **220**. The chip **210** with bumps **225** on contacts **222** is bonded to an antenna **230**

contained on the substrate **220**. The package is sealed by thin flexible laminations **270** consisting of a hot-melt adhesive **250** such as EVA on the inside and an outer coating **260** of a tough polymeric material on the outside.

The antenna is manufactured as an integral part of the substrate. It will consist of thin, typically 25 to 35 micron thick copper lines which have either been etched onto a copper/organic laminate or plated on the organic surface. The thinness of the copper maintains the flexibility of the substrate. Typical materials used are polyester or polyimide for the organic and electroplated or rolled annealed copper. The copper may be gold or tin plated to facilitate bonding. The chip is connected to the antenna lines by means of bumps on the chip, either plated gold bumps for thermo-compression bonding or C4 solder bumps for solder bonding are preferred. The bumps **225** then become the connecting lines. Since they are only on the order of 25 microns or so they will not degrade electrical performance by introducing unwanted inductance into the circuit. The novel design has a single metal layer with no vias (between-plane connectors through a dielectric layer) in the flexible continuous film. By using only one level of metal to produce the antenna and interconnections, the package is kept thin. Further novelty of the invention includes arranging the components (chip and antenna and possibly a battery) in adjacent proximity to one another. This means that the components are close (i.e., not stacked). In a more preferred embodiment the closeness is insured because the chip **210** is bonded directly to the antenna **230** without the use of crossovers in the circuit. This is accomplished by using either a dipole, loop or folded dipole antenna that is resonant rather than using a multiloop antenna which requires cross-overs for connection. Thus all of the wiring is placed in a single plane. Keeping the antenna adjacent to the chip, avoiding cross-overs and stacking, also contributes to keeping the package thin.

To maintain the thinness of the package, the chill is made to be 225 to 375 microns thick by thinning. In general, semiconductors are manufactured on thick wafers, up to 1 mm thick. Thinning may be done by polishing or backgrinding of the wafer after manufacture. All elements and bonds are very thin. The elements are preferably: the chip (and battery if used) are 10 to 12 mils (250 to 300 microns) thick or thinner; the bonding structures are 2 mils (50 um) or less; laminating materials 2 to 4 mils (50 to 125 um) per side; to produce total thickness preferably of about 20 mils (500 um) or less but in any case less than 30 mils (750 um). Bonding mechanisms do not add to thickness of the tag as would techniques like wirebonding.

Although not required in one preferred embodiment, a unique flexible covering material **270** may be laminated upon one or both sides of the package. In another preferred embodiment, the material consists of two layers (**250**, **260**). A soft copolymer such as ethyl-vinyl-acetate is located on the inside **250** surface of the cover. Tough polyester is located on the outside **260** surface. This combination provides environmental protection while maintaining the flexibility of the package. Typical thicknesses of the covers range from 50 to 125 microns. Alternately, a single layer of laminate such as polyethylene, polyester, mylar or polyimide may be used for covering.

FIG. **3** shows a side view of a unique RF ID tag **300**. The chip **310** with contacts **322** and bumps **325** is bonded to antenna **330** thru window **315** in substrate **320**. In a more preferred embodiment, encapsulant **340** is used to protect the chip **310**, the bonds **325** on contacts **322**, connected to antenna **330** located in window **315** between substrate **320** from environmental exposure. In a still more preferred

embodiment, the package is sealed by thin flexible laminations **370** consisting of hot melt adhesive **350** such as EVA, phenolic butyral, or silicone adhesive on the inside and an outer coating **360** of a tough polymeric material (such as polyester, mylar, polyimide, and polyethylene) on the outside. In an alternative preferred embodiment, layer **370** comprises a single layer of organic material.

In order to further reduce the thickness of the package, the substrate is manufactured with a window allowing the insertion of the chip into the window. Thus, the thickness of the substrate is not added to the thickness of the chip. The window is produced in organic materials, polyimide or polyester by either etching or punching. In addition, the window may be used to allow the coating of the chip with a thin layer of encapsulation material. Hysol epoxy **4510** is one such material. The encapsulant does not add substantially to the total package thickness, adding perhaps 50 microns, but does provide additional environmental protection for the chip. Opaque materials in the encapsulant protect light sensitive circuits on the chip. In this embodiment, the antenna and the center of the chip can be coplanar.

FIG. **4** shows a top view of the thin RF ID tag **400**. The chip **410** is located within a window **450** placed in a flexible substrate **420**. The chip **410** has contacts **425** which are connected to a antenna **430** contained on the substrate.

FIG. **5** shows a top view of the thin RF ID tag **500**. The chip **510** placed in the window **550** has contacts **525** which are connected to more than one folded dipole antenna **530** and **531** contained on the substrate.

FIG. **6** shows a top view of the thin tag **600**. The semiconductor chip **610** is connected to a folded dipole antenna **630** by means of contacts **625**. The antenna is contained in the substrate **620** as described above. A thin battery **660** is connected to the chip **610** by leads **661** and **662** bonded at contacts **625**.

The battery has short connecting lines **661** and **662** providing electrical continuity between the battery and the chip. The battery is placed adjacent to the chip, not stacked upon the chip. The battery thickness of about 0.25 mm keeps the battery flexible. The antenna is designed such that it is also adjacent to the battery. There is no overlap. The wiring is kept in one plane and all of the elements (chip, battery, antenna) are coplanar; there is no stacking. As a result, the package is thin and flexible.

The bonding method for attaching batteries to prior art radio frequency tags include some of the techniques described below, i.e., soldering, conducting adhesive; and wire bonding. In addition, spot welding may be used. In spot welding, shown below in FIG. 7E, the battery connection pads are pressed to contacts on the substrate while a low-voltage high-current pulse bonds the two metals together.

In one preferred embodiment, the metallurgies on the battery, chip, and substrate are such that the battery attaching mechanism is consistent with the method and mechanism of the chip attachment. For example, use of tin plating on the substrate to enable chip bonding may preclude use of conductive adhesive to attach the battery but might allow use of gold plating to enable attaching of both.

A more preferred embodiment used to make a thin flexible rugged package uses robust chip attach techniques such as thermocompression (TC) bonding used in TAB (tape automated bonding) technology. Using TC bonding for the chip and spot welding for the battery is a novel combination of bonding techniques that enables attachment of the battery to a flexible substrate **620**. In one preferred embodiment, the substrate is a TAB polyimide or polyester.

FIG. **7** shows different types of bonding available in the prior art to attach chips to circuitry that are on the substrate when producing an RF tag. These include thermocompression bonding, ultrasonic single point bonding, soldering, and conductive adhesive.

In FIG. 7A, using thermocompression bonding, suitable metal surfaces are brought into contact with pressure **750** and heat **740** applied by thermode **720** to form a metal-to-metal bond **760** usually gold bumps **730** on chip **710** to gold-plated leads **706** on substrate **705** which rests on lower thermode **780**. Many leads are bonded at once (gang bonding). This is used extensively for reel-to-reel TAB (tape automated bonding).

FIG. 7B shows ultrasonic singlepoint bonding a variation on thermocompression bonding for TAB where some ultrasonic energy is substituted for some pressure. One bond is done at a time. This bonding type also requires gold-to-gold metallurgy. Bonding tip **751** applies pressure **731** and ultrasonic energy **741** while pressing lead **721** to bump **725** on chip **711** resting on lower support **705**.

FIG. 7C shows soldering or C4 solderbonding where small lead/tin solder bumps **746** are used as the connecting medium between chip **716** and pads **726** on substrate **736**. The reflow is carried out while the substrate is carried on platform **756** through oven **786**. This usually requires the application of solder flux for reflow of the solder at elevated temperature.

FIG. 7D shows conducting adhesive bonding where a metal-filled adhesive **744** is applied to form the connecting medium between chip pads **740** on chip **714** and the substrate pads **724** on the substrate **734**. Heat **774** and pressure **784** are applied by pressing between thermodes **764** and **754**.

FIG. 7E shows spot welding where welding tips **755** and **765** separated by gap **775** are pressed to conductor **745** held in contact with conductor **735** placed on insulating substrate **725**. Current **785** heats the welding tips **755** and **765** to make the bond.

FIG. **8** shows an RF postage stamp **800** containing a thin RF tag **810** which consists of antenna **815**, battery **820**, and chip **830** affixed to envelope or package **840**. This tag **810** can be any of the embodiments described above. In this application, the cover (typically **270** of FIG. **2** and **370** of FIG. **3**) for the tag is the paper of the stamp. Adhesives, such as acrylics, are used to sandwich the tag between thin paper. These adhesives would correspond to the layer **250** in FIG. **2** and **350** in FIG. **3**. The top surface (of one side **270**, **370**) can be printed with the appropriate graphics while the bottom surface has a pressure sensitive adhesive (of the other side **270**, **370** in the case of a tag laminated on two sides), also acrylic, to bond the stamp to a package or letter envelope. The RF tag would contain information about mailing used to track a letter or parcel on which the stamp is placed. Alternatively, the RF tag **850** could be enclosed in the parcel membrane or in the wall of the envelop **840**. In another, embodiment the RF tag could be placed within the parcel or envelop.

FIG. **9** shows the thin RF tag **920** embedded in the cover **910** of passport **930** to form an RF passport **900**. Here the tag is sandwiched between the paper covers of the passport. The tag can have an environmental laminate(s) (**270**, **370**) as described above or alternatively, the passport cover can be used as the tag laminate(s) (**270**, **370**). The tag contains in its memory information on the identity of the passport owner, visas, dates of entry, restrictions, or any other desirable information. The information may be in encrypted form for added security. The encryption "key" would be a software

code that is held and used solely by the agency issuing the passport. The deencryption key may be made public so that anyone (with a public deencryption key) can read information in the memory of the tag but only the agency having the encryption key can write information to the tag.

FIG. **10** shows admission ticket **1010** containing RF tag **1020**. The tag is again enclosed between paper covers or other laminates. The ticket may be a simple admission ticket or entitlement such as an airline ticket or a food stamp. However, the tagged ticket may also serve as a tracking device.

FIG. **11** shows a CD **1140** enclosed in box **1120** with an RF ID antitheft tag **1130** affixed to the box **1120**. The tag serves as both a barcode replacement, inventory device, point of sale device, and as an antitheft device. Information on product variety, price, date of manufacture and sale may be carried by the tag. Additional bits of information in the memory of the circuit may be changed at the time of sale to indicated that the item may be taken from the store.

FIG. **12** shows ISO standard credit card **1210** containing an RF tag **1220**. The credit card may serve as an ATM card, frequent flyer card, library card, phone card, employee ID, medical ID card, gasoline credit card or any credit or debit card. The covers (laminates **270**, **370**) of the tag could be the covers of the credit card, preferably PVC laminations. The core of the credit card, 0.5 mm thick, has a window placed in it at the time of manufacture. The 0.5 mm thick tag package is placed in the window and then sealed into the card. The resulting credit card, including the tag, will not only have the length and width that meet the ISO standard, but the thickness as well.

In another embodiment of the present invention, shown in FIG. **13**, the RF tag **1320** is place within a vehicular drivers license **1310** in the same manner as described above. This allows information on the RF tag to be used for personal identification, driving record, organ donor information, restrictions, proof of identity and age, etc. The information can be encrypted for security purposes.

We claim:

1. A thin flexible electronic radio frequency tag circuit comprising;

a. an insulating, flexible substrate;

b. an antenna that is an integral part of the substrate and that has terminals;

c. a circuit chip having a modulator circuit, a logic circuit, a memory circuit, and chip connectors and being on the substrate in adjacent proximity to the antenna;

d. one or more connecting lines between the antenna terminals and the chip connectors, the connecting lines being coplanar with the antenna and antenna terminals.

2. A circuit, as in claim **1**, wherein the substrate is organic.

3. A circuit, as in claim **2**, wherein the substrate is polyimide.

4. A circuit, as in claim **2**, wherein the substrate is polyester.

5. A circuit, as in claim **1**, wherein the connecting lines are bonded to the chip connectors using any of the bonding types including thermal compression, single point bonding, C4 bonding, and conductive adhesive.

6. A circuit, as in claim **1**, wherein the substrate has an aperture into which the chip is placed.

7. A circuit, as in claim **1**, wherein the chip is covered by an encapsulant.

8. A circuit, as in claim **7**, wherein the encapsulant is opaque.

9. A circuit, as in claim **7**, wherein an organic cover surrounds the chip, the encapsulant, the substrate, and the antenna.

10. A circuit, as in claim **9**, wherein the organic cover is one of the materials including polyester, mylar, polyimide, and polyethylene.

11. A circuit, as in claim **1**, that is laminated by one or more layers.

12. A circuit, as in claim **11**, that is laminated by a two layer laminate comprising a hard outer layer and a adhesive inner layer.

13. A circuit, as in claim **12**, wherein the adhesive is one of the materials including ethyl vinyl acetate (EVA), phenolic butyral, and silicone adhesive.

14. A circuit, as in claim **11**, wherein the circuit is laminated on one side.

15. A circuit, as in claim **11**, wherein the circuit is laminated on two sides.

16. A circuit, as in claim **11**, wherein the circuit has at least one tag dimension that is less than 760 microns (30 mils).

17. A circuit, as in claim **16**, that is encapsulated as an International Organization for Standardization (ISO) standard credit card size package.

18. A circuit, as in claim **1**, wherein the antenna is a resonant antenna and is any one of the following structures including folded dipole, dipole, and loop.

19. A circuit, as in claim **1**, wherein a battery is also affixed to the substrate in adjacent proximity to the antenna and chip and is connected by one or more battery connecting lines to two or more chip battery contacts wherein the battery connecting lines and the battery contacts are coplanar with the antenna and connecting lines.

20. A circuit, as in claim **19**, wherein the battery contacts are connected to the battery connecting lines by any of the bonding types including spot welding, soldering, thermocompression bonding, and conducting adhesive.

21. A circuit, as in claim **19**, wherein the battery contacts are connected by spot welding and the chip contacts are connected to the antenna by thermocompression bonding.

22. A circuit, as in claim **1**, wherein the chip has at least one chip dimension less than 300 microns (12 mils), the antenna has at least one antenna dimension less than 35 microns (1.4 mils), and the substrate has at least one substrate dimension less than 125 microns (5 mils) whereby the circuit has at least one circuit dimension less than 508 microns (20 mils).

23. A circuit, as in claim **22**, wherein the chip memory has information about mailing and the circuit is applied to a mailed letter or parcel.

24. A circuit, as in claim **23**, wherein the RF tag is enclosed within a stamp.

25. A circuit, as in claim **23**, wherein the RF tag is enclosed within the parcel or envelop membrane.

26. A circuit, as in claim **22**, wherein the tag is enclosed in a passport.

27. A circuit, as in claim **22**, wherein the tag is enclosed in an admission ticket.

28. A circuit, as in claim **22**, that is enclosed in an article and the tag has information to prevent theft.

29. A circuit, as in claim **22**, wherein the tag is enclosed in a drivers license.

* * * * *

EXHIBIT B

US005912632A

United States Patent [19]

Dieska et al.

[11] **Patent Number: 5,912,632**

[45] **Date of Patent: Jun. 15, 1999**

[54] **SINGLE CHIP RF TAG OSCILLATOR CIRCUIT SYNCHRONIZED BY BASE STATION MODULATION FREQUENCY**

[75] Inventors: **David E. Dieska**, Longwood, Fla.; **Daniel Joseph Friedman**, Tarrytown, N.Y.; **Kenneth Alan Goldman**, Norwalk, Conn.; **Harley Kent Heinrich**, Brewster, N.Y.

[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **08/780,765**

[22] Filed: **Jan. 8, 1997**

[51] **Int. Cl.**[6] **H04Q 5/22**; H04Q 7/00; H03L 7/00

[52] **U.S. Cl.** **340/825.54**; 455/31.1; 455/37.1; 331/23; 331/10

[58] **Field of Search** 340/825.5, 825.54, 340/825.36, 825.69, 825.72; 342/51; 455/31.1, 37.1, 34.3, 38.3; 331/23

[56] **References Cited**

U.S. PATENT DOCUMENTS

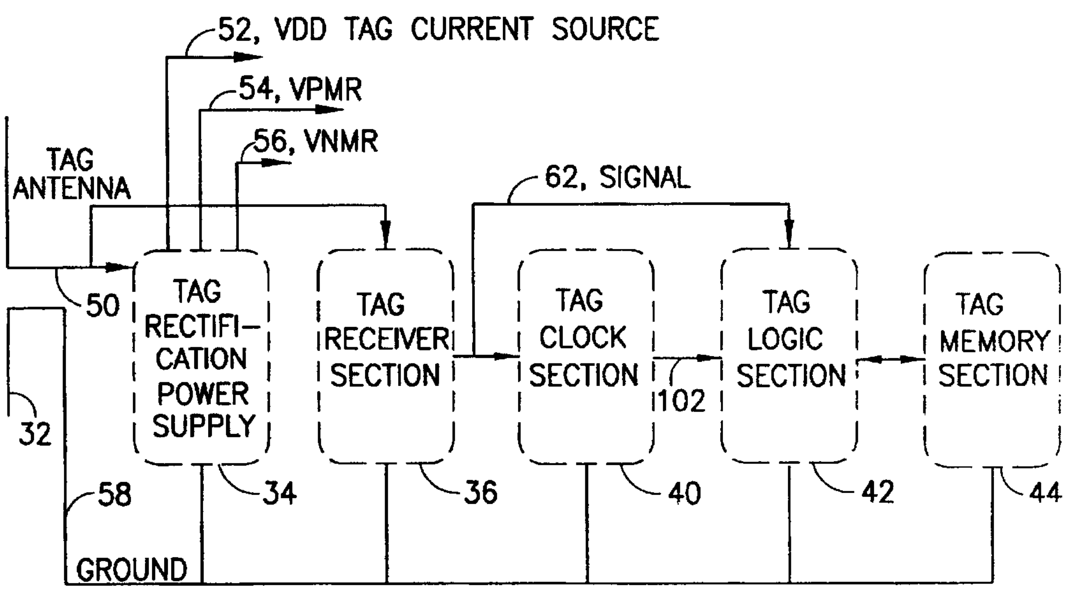
4,075,632	2/1978	Baldwin et al.	342/42
4,786,907	11/1988	Koelle	342/51
5,313,198	5/1994	Hirao et al.	340/825.54
5,525,991	6/1996	Nagura et al.	342/42

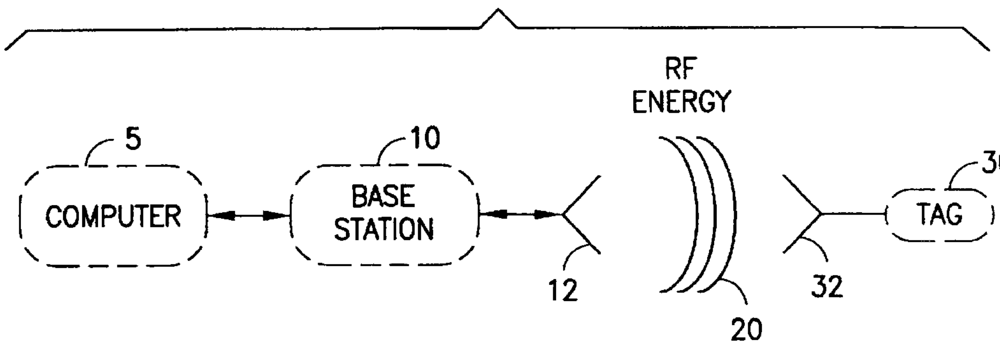
Primary Examiner—Michael Horabik
Assistant Examiner—Anthony A. Asongwed
Attorney, Agent, or Firm—Rodney T. Hodgson

[57] **ABSTRACT**

A Radio Frequency (RF) transponder (tag), method, and system, whereby the tag has a low current tag oscillator, the oscillation frequency of the tag oscillator set by RF signal from a base station.

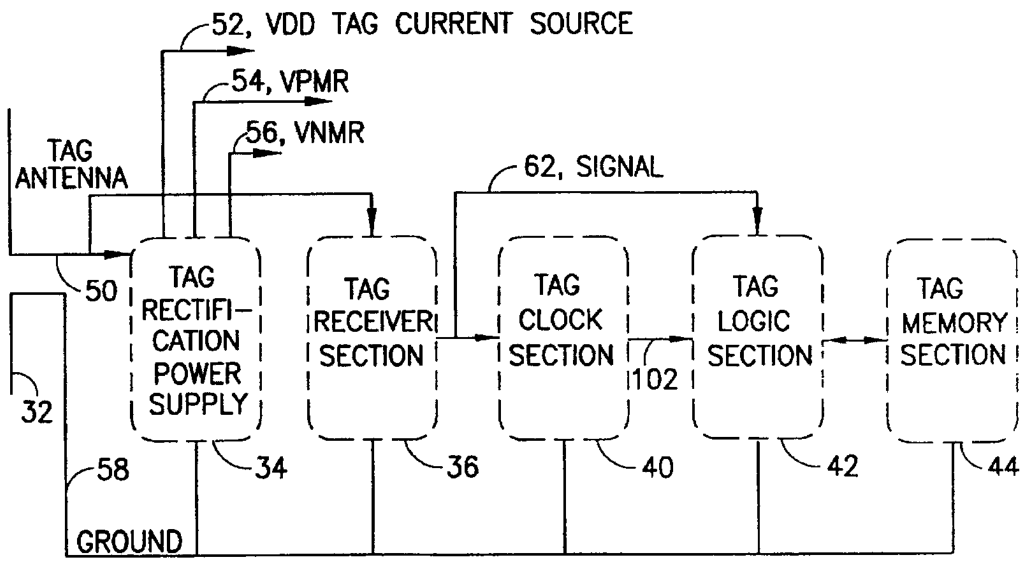
28 Claims, 9 Drawing Sheets





RF ENERGY
5
COMPUTER
10
BASE STATION
12
20
30
TAG
32

FIG. 1



52, VDD TAG CURRENT SOURCE
54, VPMR
56, VNMR
TAG ANTENNA
62, SIGNAL
50
32
TAG RECTIFICATION POWER SUPPLY
TAG RECEIVER SECTION
TAG CLOCK SECTION
102
TAG LOGIC SECTION
TAG MEMORY SECTION
58
34
36
40
42
44
GROUND

FIG. 2

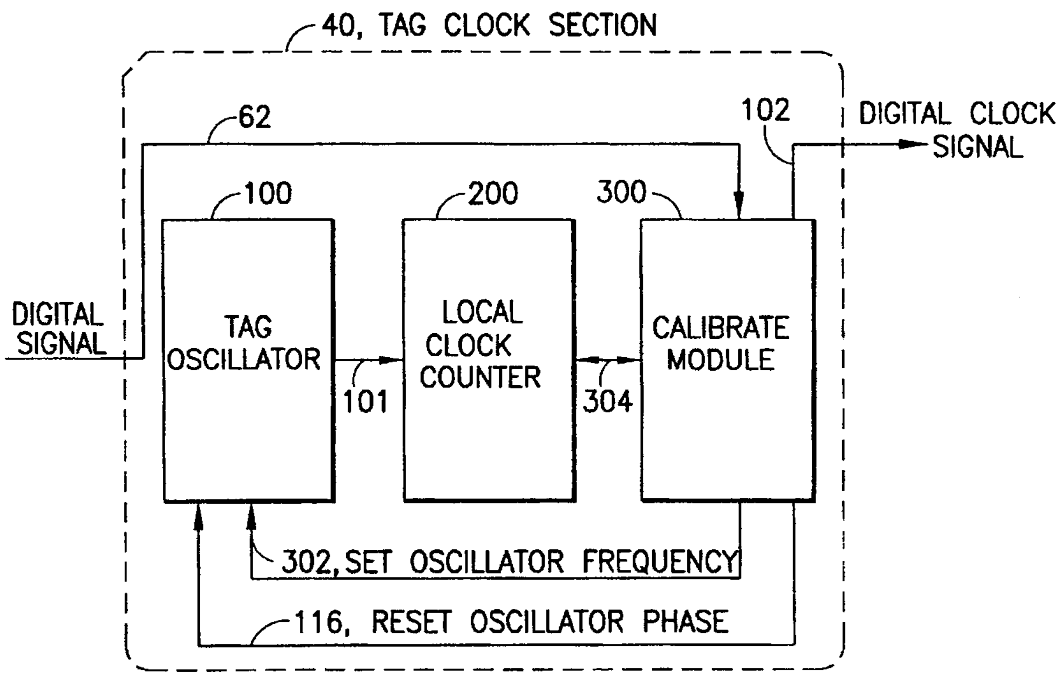

40, TAG CLOCK SECTION
62
102
DIGITAL CLOCK SIGNAL
100
200
300
DIGITAL SIGNAL
TAG OSCILLATOR
LOCAL CLOCK COUNTER
CALIBRATE MODULE
101
304
302, SET OSCILLATOR FREQUENCY
116, RESET OSCILLATOR PHASE

FIG.3

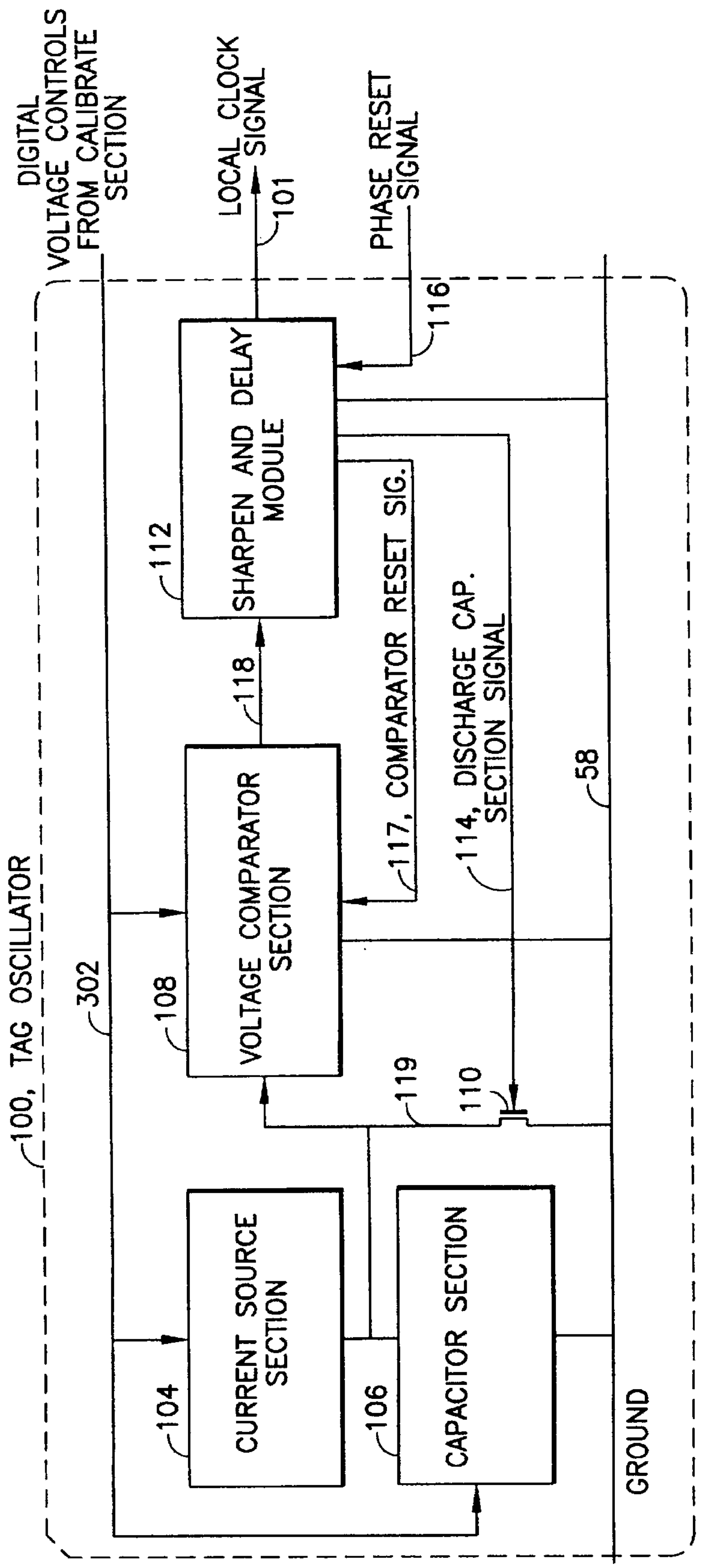

DIGITAL VOLTAGE CONTROLS FROM CALIBRATE SECTION
LOCAL CLOCK SIGNAL
101
PHASE RESET SIGNAL
116
SHARPEN AND DELAY MODULE
112
118
VOLTAGE COMPARATOR SECTION
108
117, COMPARATOR RESET SIG.
114, DISCHARGE CAP. SECTION SIGNAL
58
100, TAG OSCILLATOR
302
119
110
CURRENT SOURCE SECTION
104
CAPACITOR SECTION
106
GROUND

FIG. 4

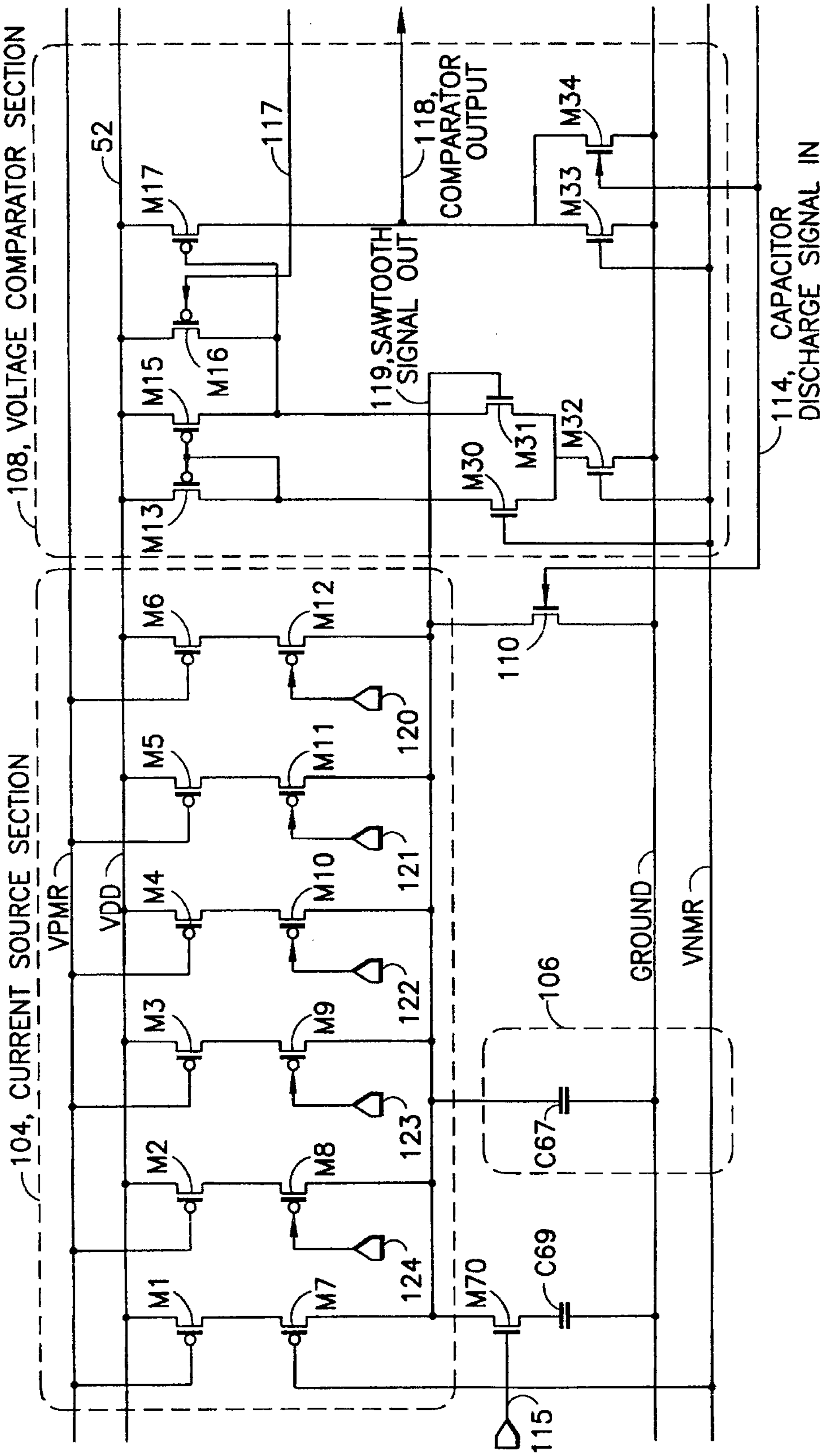

108, VOLTAGE COMPARATOR SECTION
104, CURRENT SOURCE SECTION
VPMR
VDD
52
117
118, COMPARATOR OUTPUT
119, SAWTOOTH SIGNAL OUT
114, CAPACITOR DISCHARGE SIGNAL IN
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
M13
M15
M16
M17
M30
M31
M32
M33
M34
M70
110
106
C67
C69
120
121
122
123
124
115
GROUND
VNMR

FIG.5a

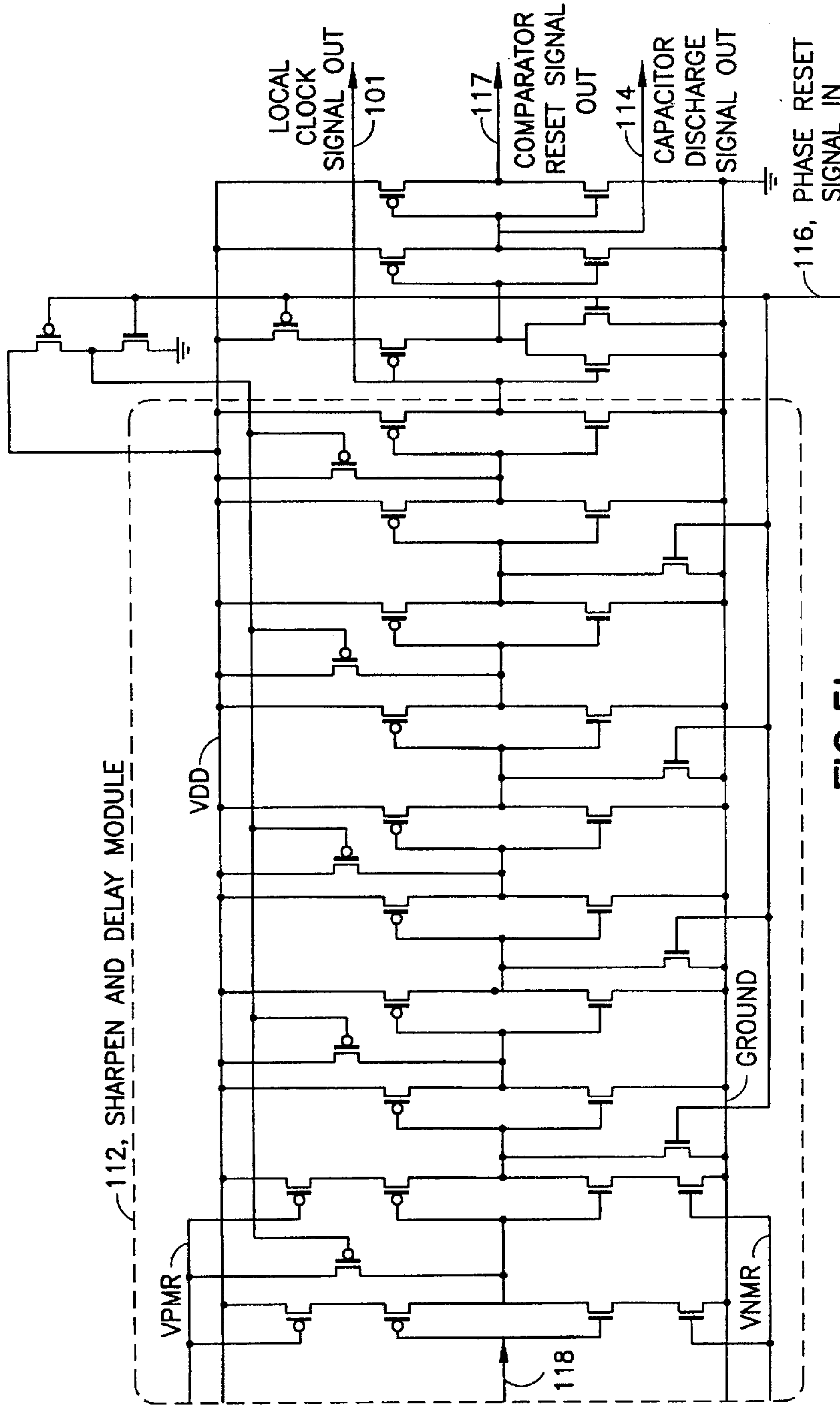

LOCAL CLOCK SIGNAL OUT
101
117
COMPARATOR RESET SIGNAL OUT
114
CAPACITOR DISCHARGE SIGNAL OUT
116, PHASE RESET SIGNAL IN
112, SHARPEN AND DELAY MODULE
VDD
GROUND
VPMR
VNMR
118

FIG.5b

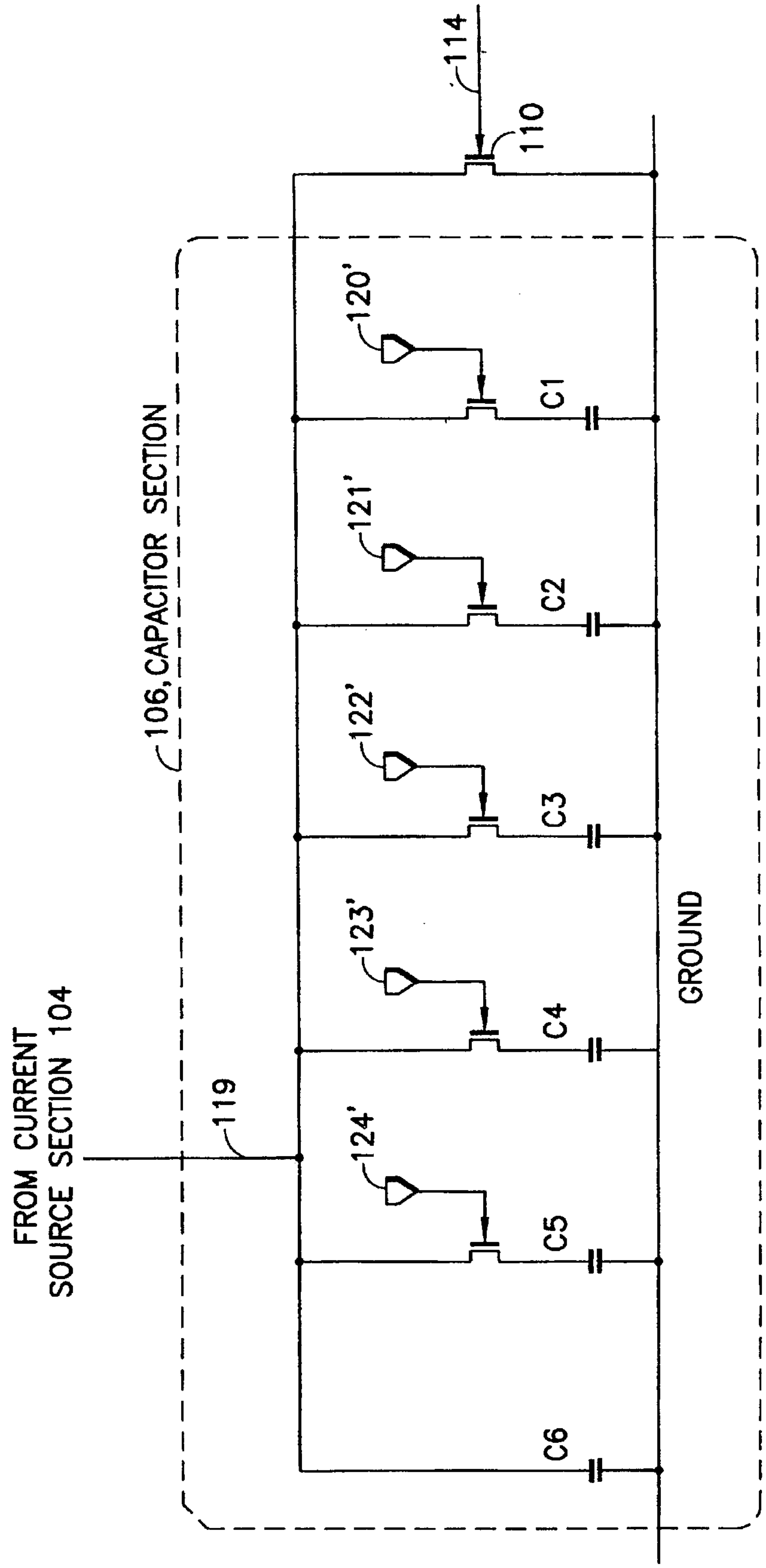

114
110
106, CAPACITOR SECTION
120'
121'
122'
123'
124'
C1
C2
C3
C4
C5
C6
GROUND
119
FROM CURRENT SOURCE SECTION 104

FIG.6

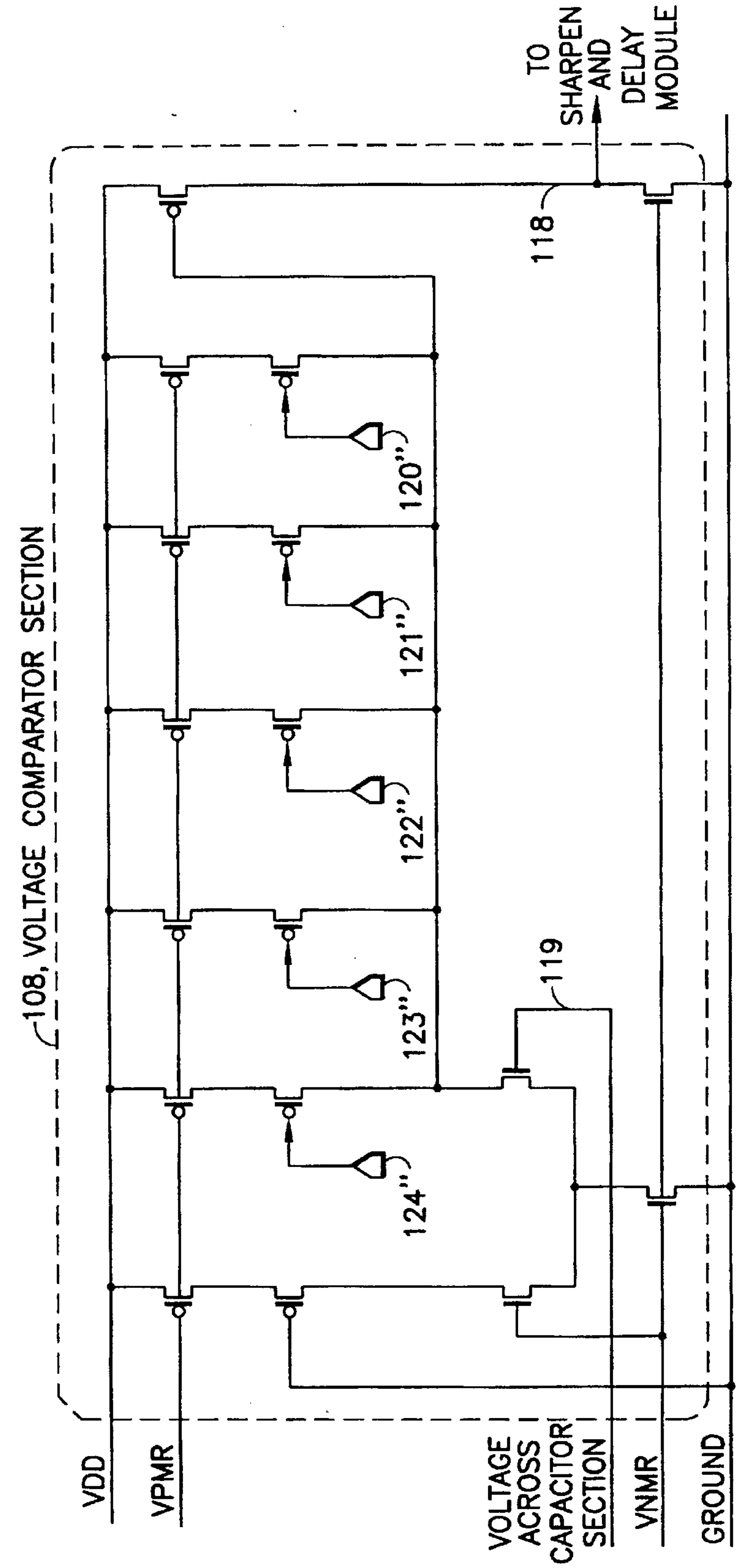

TO SHARPEN AND DELAY MODULE
118
108, VOLTAGE COMPARATOR SECTION
120''
121''
122''
123''
124''
119
VDD
VPMR
VOLTAGE ACROSS CAPACITOR SECTION
VNMR
GROUND

FIG. 7

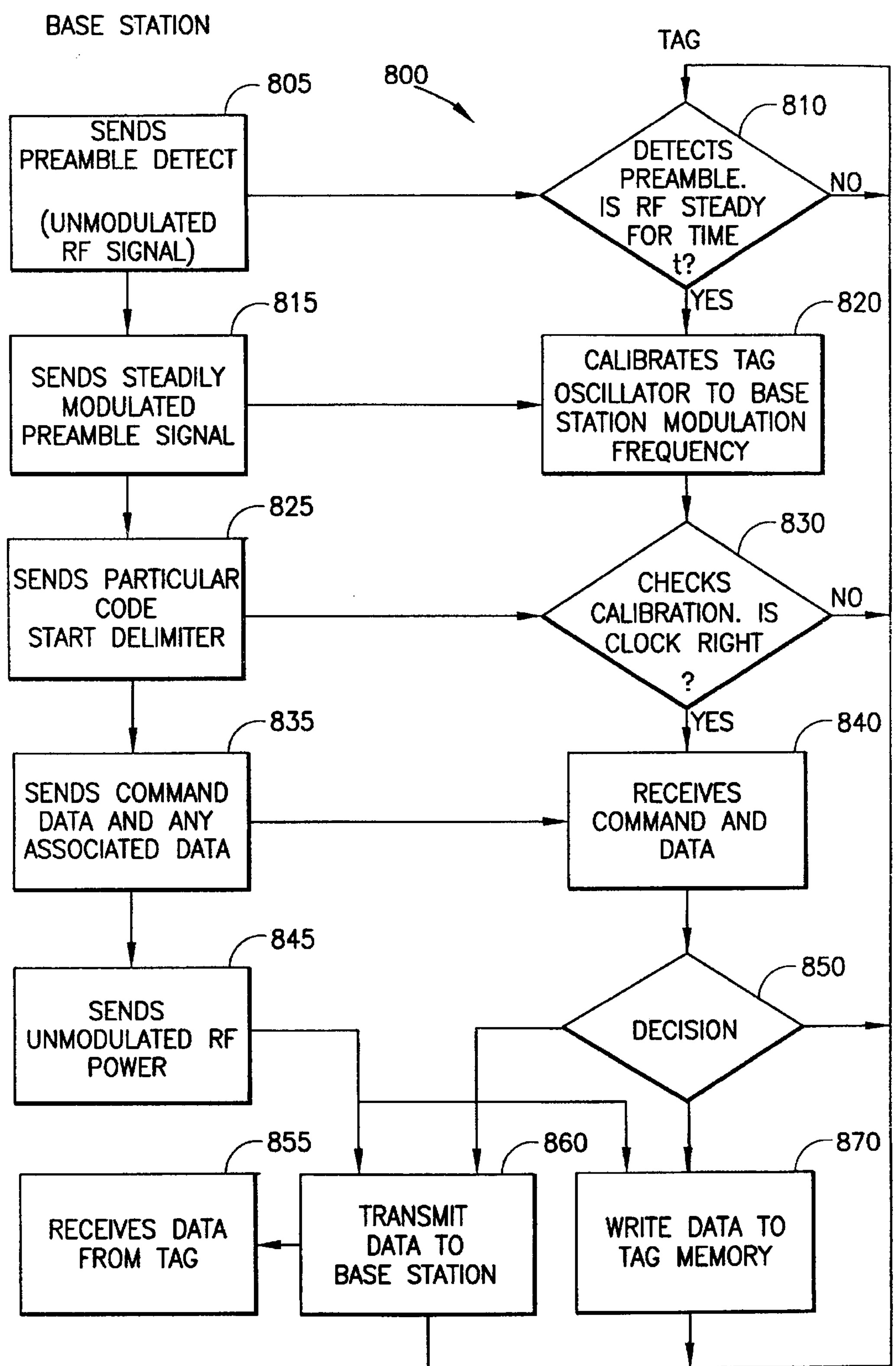

BASE STATION
TAG
800
805
SENDS PREAMBLE DETECT (UNMODULATED RF SIGNAL)
810
DETECTS PREAMBLE. IS RF STEADY FOR TIME t?
NO
YES
815
SENDS STEADILY MODULATED PREAMBLE SIGNAL
820
CALIBRATES TAG OSCILLATOR TO BASE STATION MODULATION FREQUENCY
825
SENDS PARTICULAR CODE START DELIMITER
830
CHECKS CALIBRATION. IS CLOCK RIGHT ?
NO
YES
835
SENDS COMMAND DATA AND ANY ASSOCIATED DATA
840
RECEIVES COMMAND AND DATA
845
SENDS UNMODULATED RF POWER
850
DECISION
855
RECEIVES DATA FROM TAG
860
TRANSMIT DATA TO BASE STATION
870
WRITE DATA TO TAG MEMORY

FIG.8

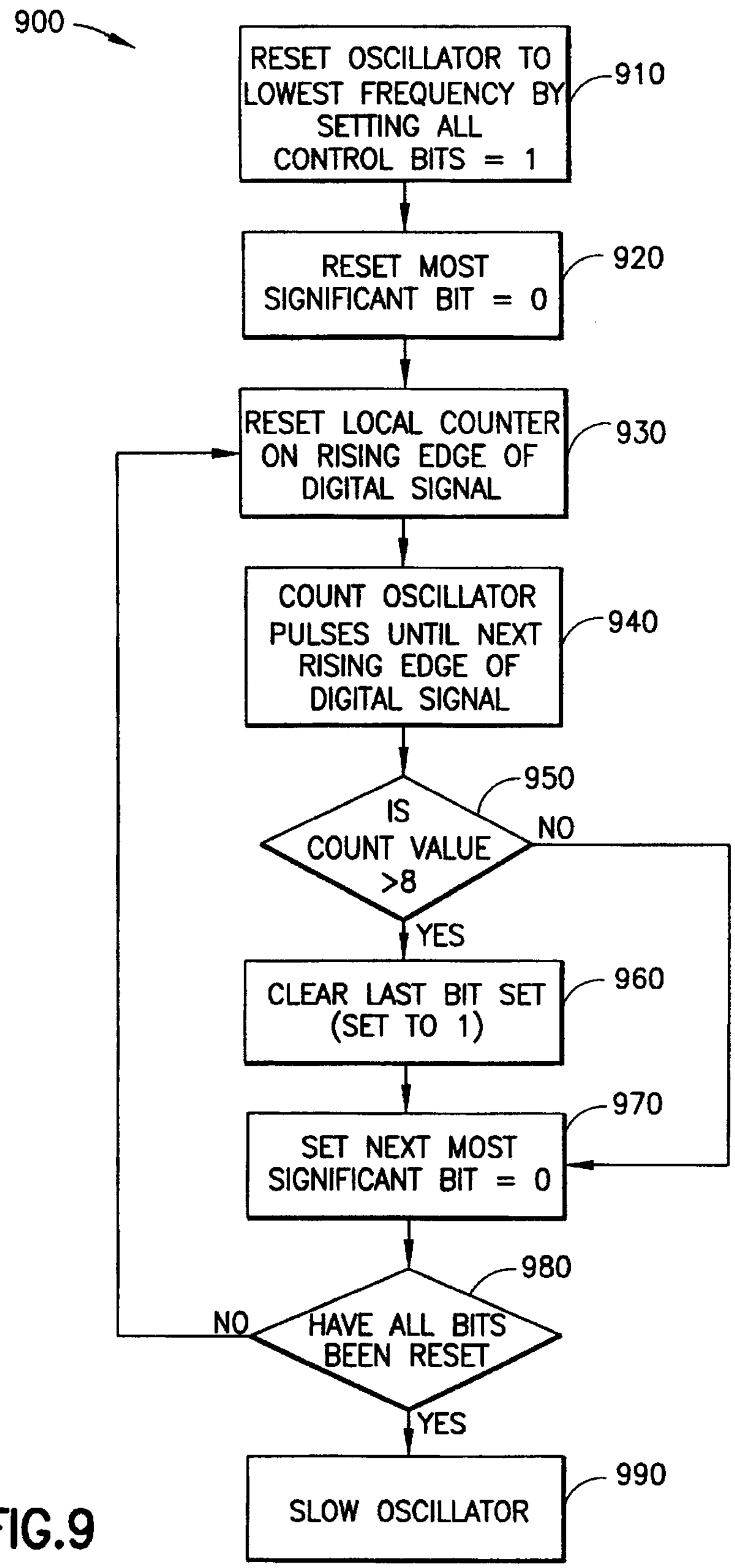

900
RESET OSCILLATOR TO LOWEST FREQUENCY BY SETTING ALL CONTROL BITS = 1
910
RESET MOST SIGNIFICANT BIT = 0
920
RESET LOCAL COUNTER ON RISING EDGE OF DIGITAL SIGNAL
930
COUNT OSCILLATOR PULSES UNTIL NEXT RISING EDGE OF DIGITAL SIGNAL
940
IS COUNT VALUE >8
950
NO
YES
CLEAR LAST BIT SET (SET TO 1)
960
SET NEXT MOST SIGNIFICANT BIT = 0
970
HAVE ALL BITS BEEN RESET
980
NO
YES
SLOW OSCILLATOR
990

FIG.9

SINGLE CHIP RF TAG OSCILLATOR CIRCUIT SYNCHRONIZED BY BASE STATION MODULATION FREQUENCY

FIELD OF THE INVENTION

The field of the invention is the field of Radio Frequency (RF) transponders (RF Tags) which receive RF electromagnetic radiation from a base station and send information to the base station by modulating the load of an RF antenna.

BACKGROUND OF THE INVENTION

RF Tags can be used in a multiplicity of ways for locating and identifying accompanying objects, items, animals, and people, whether these objects, items, animals, and people are stationary or mobile, and transmitting information about the state of the of the objects, items, animals, and people. It has been known since the early 60's in U.S. Pat. No. 3,098,971 by R. M. Richardson, that electronic components on a transponder could be powered by radio frequency (RF) power sent by a "base station" at a carrier frequency and received by an antenna on the tag. The signal picked up by the tag antenna induces an alternating current in the antenna which can be rectified by an RF diode and the rectified current can be used for a power supply for the electronic components. The tag antenna loading is changed by something that was to be measured, for example a microphone resistance in the cited patent. The oscillating current induced in the tag antenna from the incoming RF energy would thus be changed, and the change in the oscillating current led to a change in the RF power radiated from the tag antenna. This change in the radiated power from the tag antenna could be picked up by the base station antenna and thus the microphone would in effect broadcast power without itself having a self contained power supply. In the cited patent, the antenna current also oscillates at a harmonic of the carrier frequency because the diode current contains a doubled frequency component, and this frequency can be picked up and sorted out from the carrier frequency much more easily than if it were merely reflected. Since this type of tag carries no power supply of its own, it is called a "passive" tag to distinguish it from an active tag containing a battery. The battery supplies energy to run the active tag electronics, but not to broadcast the information from the tag antenna. An active tag also changes the loading on the tag antenna for the purpose of transmitting information to the base station.

The "rebroadcast" or "reflection" of the incoming RF energy at the carrier frequency is conventionally called "back scattering", even though the tag broadcasts the energy in a pattern determined solely by the tag antenna and most of the energy may not be directed "back" to the transmitting antenna.

In the 70's, suggestions to use tags with logic and read/write memories were made. In this way, the tag could not only be used to measure some characteristic, for example the temperature of an animal in U.S. Pat. No. 4,075,632 to Baldwin et. al., but could also identify the animal. The antenna load was changed by use of a transistor. A transistor switch also changed the loading of the transponder in U.S. Pat. No. 4,786,907 by A. Koelle.

Prior art tags have used electronic logic and memory circuits and receiver circuits and modulator circuits for receiving information from the base station and for sending information from the tag to the base station.

The continuing march of semiconductor technology to smaller, faster, and less power hungry has allowed enormous increases of function and enormous drop of cost of such

tags. Presently available research and development technology will also allow new function and different products in communications technology.

Prior art tags which use a different frequency than that of the base station carrier frequency are disadvantageous in that the tag and base station antennas usually have maximum efficiency if it they are designed for a single frequency.

Prior art battery tags which use the same frequency as that of the base station must modulate the antenna reflectance with a well defined modulation frequency so that the base station can distinguish the modulated reflected signal from the various sources of noise. Prior art battery tags carry an oscillator as part of the circuitry needed to receive and send data between the tag and the base station. This oscillator needs a local frequency standard to fix the tag modulation frequency so that the base station can easily and cheaply receive and demodulate the modulated signal sent by the tag. Such local frequency standards are very expensive and hard to integrate on a monolithic semiconductor chip. The tags require an oscillator which draws a lot of current from the tag power supply, either from a battery tag or a passive tag, which lowers either the life of the battery or the range of the tag, respectively. In addition, the base station may have to adjust to the modulation frequency sent out by the tag, which requires that the base station listens to the tag in the first step of the communication procedure, instead of talking to the tag first. This complicates communication procedures when there are multiple tags in the field. Each tag may be sending signals to the base station with a different modulation frequency, and the signals will interfere.

RELATED APPLICATIONS

Copending patent applications assigned to the assignee of the present invention and hereby incorporated by reference, are:

- Ser. No. 08/303,965 filed Sep. 9, 1994 entitled RF Group Select Protocol, by Cesar et. al now U.S. Pat. No. 5,673,037;
- Ser. No. 08/304,340 filed Sep. 9, 1994 entitled Multiple Item RF ID protocol, by Chan et. al. now U.S. Pat. No. 5,550,547;
- Ser. No. 08/521,898 filed Aug. 31, 1995 entitled Diode Modulator for RF Transponder by Friedman et al. now U.S. Pat. No. 5,606,325;
- application submitted Aug. 9, 1996 entitled RFID System with Broadcast Capability by Cesar et al.; and
- application submitted Jul. 29, 1996 entitled RFID transponder with Electronic Circuitry Enabling and Disabling Capability, by Heinrich et al.

OBJECTS OF THE INVENTION

It is an object of the invention to produce an RF transponder comprising circuits which can be made at low cost. It is a further object of the invention to produce an RF transponder which can be used at high frequencies. It is a further object of the invention to produce an RF transponder with maximum range. It is a further object of the invention to produce an RF transponder with circuits which require very little current. It is a further object of the invention to produce an electronic chip for an RF transponder which can be produced simply with standard semiconductor manufacturing techniques. It is a further object of the invention to produce a communication system for communicating with the RF transponder of the present invention. It is a further object of the invention to produce a system for controlling

the communication system using the present invention. It is a further object of the invention to produce a system for using and changing information received from the transponder of the present invention.

SUMMARY OF THE INVENTION

The present invention is to have a passive RF tag with a tag oscillator with an oscillation frequency which the tag can lock to a signal sent from the base station to the tag. An innovative low current oscillator design accomplishes this invention. Innovative low current ancillary circuits are also provided. The preferred signal is the modulation frequency of the modulated RF signal that the base station sends to the tag. In this way, an expensive local frequency standard on the tag is not needed, and an inexpensive oscillator can be constructed solely from the transistors and capacitors which are easily and cheaply made on a single chip RF tag. The base station is also cheaper, since the tag sends information modulated at a frequency related to the modulation frequency of the base station, and the base station does not have to have an expensive oscillator circuit which tracks wide excursions of the tag modulation frequency. The result is better noise performance since the base station looks in a much narrower frequency band for the tag signal than would otherwise be the case with inexpensive oscillator circuits on the tag.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**. A system of a base station and an RF tag.

FIG. **2**. A block diagram of part of the RF tag.

FIG. **3**. A block diagram of the tag clock section.

FIG. **4**. A block diagram of a preferred tag oscillator.

FIG. **5***a*. and **5***b*. A circuit diagram for a preferred embodiment of a tag oscillator.

FIG. **6**. A circuit diagram for an alternative preferred embodiment of a capacitor section for a tag oscillator.

FIG. **7**. A circuit diagram for an alternative preferred embodiment of a voltage comparator section for a tag oscillator.

FIG. **8**. A flow chart of a preferred method of implementing and using the apparatus of the invention.

FIG. **9**. A flow chart of a preferred method of calibrating the tag oscillator.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a system of a base station **10** having an associated computer **5** sending RF energy **20** from base station antenna **12** to a tag antenna **32** associated with an RF tag **30**. The RF frequency f_0 is preferably above 100 MHZ, more preferably above 900 MHZ, and most preferably above 2,300 MHZ. The RF signal is preferably amplitude modulated at a frequency f_1 greater than 1 Khz, more preferably between 5 and 150 kHz, and most preferably between 20 and 60 kHz. However, the RF signal may also be modulated by frequency modulation or by phase modulation methods, as is well known in the art of RF signal propagation. The RF tag **30** may be a passive tag which receives all the energy needed to carry out the tag functions from the RF field broadcast by the base station, or it may be an active tag which carries a battery to store the required energy. An active tag may, and a passive tag will, change the loading on the tag antenna **32** to change the antenna reflectivity and thus communicate with the base station **10**.

FIG. **2** shows a block diagram of the tag antenna **32** and part of the RF tag **30**. (Neither a possible RF tag transmitter section nor other sections such as measurement sections nor alarm section nor enable/disable sections are shown.) The RF antenna **32** feeds RF power to the tag rectification power supply **34**. A battery tag would replace block **34** with a battery (not shown). In the preferred embodiment shown in FIG. **2**, a tag rectification signal receiving section **36** comprising an RF diode, a signal capacitor, and a signal capacitor current drain is separate from the tag rectification power supply, but the oscillator section of the invention is also contemplated in the case that section **36** is part of the tag rectification power supply **34**. The tag power supply **34** supplies current at voltage VDD on line **52**, and optionally supplies voltages VPMR, and VNMR on lines **54** and **56** respectively. These lines are used to power and control the various devices on the tag. The RF antenna **32** has two connections to the tag **30**, denoted here by lines **50** and **58**. Line **58** is the conventional ground.

The tag rectification signal receiving section **36** receives an RF signal which is preferably amplitude modulated at a frequency f_1 from the antenna **32** over line **50**, and rectifies and demodulates the RF signal and delivers a digital signal to the rest of the tag electronics over line **62**. If the RF is modulated with a steady modulation frequency f_1, the output of the signal receiving section **36** is preferably a series of square pulses of unit voltage at a frequency f_1. However, any pattern or subpattern in the signal sent out from the base station could be used to generate an output of the signal receiving section **36** in order to adjust the frequency and optionally the phase of the tag oscillator.

The tag clock section **40** receives the digital demodulated digital signal from line **62** and sets the tag oscillator frequency using the modulation frequency f_1 of the modulated RF signal as will be explained later.

The tag clock section **40** delivers a digital clock signal on line **102** to the tag logic section **42**, to the tag memory section **44**, and to other tag electronic sections as needed.

FIG. **3** is a block diagram of the tag clock section **40**. The tag oscillator **100** must use less than 500 microamperes of current from the tag power supply **34** in order to avoid drawing down the tag voltage VDD and lowering the range of the tag. It is more preferred that the tag oscillator uses less than 50 microamperes of current. It is even more preferred to have the tag oscillator draw less than 5 microamperes of current when the tag oscillator is oscillating with maximum oscillation frequency, and less than 150 nanoamperes of current when the tag oscillator is oscillating with minimum frequency. In a preferred embodiment, the tag oscillator **100** comprises an oscillator with a block diagram given later in FIG. **4**.

The tag oscillator frequency is set by the voltages supplied by a connection denoted **302** from a calibrate module **300**. The tag oscillator **100** supplies a local clock signal to the local clock counter **200** over line **101**. The local clock counter **200** counts the clock ticks of the local clock signal since the local clock counter **200** has been reset and passes the count to the calibrate module **300** via a connection **304**. The calibrate module **300** resets the local clock counter **200** via the connection **304** (and optionally resets the phase of the oscillator **100** over connection **116**) on a rising edge of the digital input signal on line **62**, and sets the voltages controlling the frequency of oscillator **100** to give a set number of counts between two rising edges of the digital input signal **62** when the base station **10** is sending a steadily modulated RF signal. The calibrate module **300** sends the voltages

controlling the frequency of the oscillator **100** over line **302**. The oscillator **100** frequency is thus determined by the modulation frequency of the RF energy **20** transmitted by the base station **10**. While the calibrate module may carry out its functions using a rising edge of the digital input signal, it is clear to one skilled in the art that the falling edge of the digital signal, or indeed any characteristic of the signal on line **62**, may serve as well. The calibrate module sends the digital clock signal to the rest of the tag electronics over line **102**.

FIG. **4** is a block diagram for an oscillator section **100**. A current source section **104** charges a capacitor section **106**. The voltage across capacitor section **106** on line **119** is compared with a reference voltage generated on the chip. The comparison is done in comparator section **108**, and when the voltage reaches a preset comparison voltage, the comparator section **108** sends a signal on line **118** down an optional pulse sharpening and delay section **112**. When the pulse reaches the end of the pulse sharpening and delay section **112**, a local clock signal is sent out on line **101**, and a pulse is sent back on line **114** to transistor **110** which discharges capacitor section **106** so that the voltage across capacitor section **106** falls to a low value. Then the voltage starts to build up until it again reaches the preset comparison voltage. The time between two discharges of the capacitor section **106** is the time between two ticks of the local clock. A series of narrow spikes is sent out from the oscillator section on line **101** representing ticks of the local clock.

A phase reset signal is brought in to the sharpen and delay module on line **116** when, for example, the tag detects a rising or falling edge of the digital signal on line **62**. The sharpen and delay module **112** then sends a pulse on line **114** to the transistor **110** to both discharge the capacitor section **106** and reset the phase of the local clock signal on line **101**. The phase reset signal also serves to clear the sharpen and delay line in the sharpen and delay module **112**. A signal is also sent on line **117** to clear the voltage comparator section **108** when the phase reset signal passes through the sharpen and delay line.

One or more of the sections **104**, **106**, and **108** are digitally controlled by signals from the calibrate module **300** sent out on line **302**. These calibrate module outputs are set using base station output modulation patterns. Thus, the tag oscillator frequency is controlled by the signals from the base station to be one of a plurality of possible discrete frequencies. Circuits for analog control of the tag oscillator are anticipated by the inventors, but the digital control is preferred since the circuits required are more stable and require less current.

The most preferred embodiment of the oscillator section **100** uses an innovative, very low current source section **104** with the value of the current set by the calibrate module using voltages brought to the current source section **104** on connection **302**. FIG. **5***a* shows a circuit diagram of the most preferred circuit of blocks **104**, **106**, and **108** which may produce a clock signal running at approximately 8 times the RF modulation frequency f_1.

Transistors **M2–M6** are each capable of sourcing a defined current on to capacitor C**67**, depending on whether control transistor switches **M8–M12** are on or off. Voltages at nodes **120**, **121**, **122**, **123**, and **124** which are set by voltages carried over connection **302**, control transistors **M8–M12**.

Transistor Ml supplies capacitor C**67** with a small current from the tag power supply at voltage VDD. This small current is independent of the calibrate module control on

line **302**. When nodes **120–124** are set high by voltages supplied on connection **302** from the calibrate module **300**, transistors **M8–M12** do not conduct current. The tag oscillator runs at a relatively low frequency, (since at low current the capacitor C**67** charges slowly to the comparison voltage) and the digital clock signal produced on line **102** is used to check whether an unmodulated RF signal is being sent from the base station for a sufficiently long time in the first step of the method of the invention called the preamble detect step. As will be shown later, the system then may calibrate the oscillator by setting voltages on nodes **120–124**. When the tag oscillator is running in the slowest mode, the average current draw is only 100 nA, as the current is drawn through most of the devices shown in FIG. **5***a* and FIG. **5***b* only for a very short time when there is a transition and a clock pulse is produced. As one or more of the control transistors **M8–M12** are turned on, the oscillator runs faster, and the feedback from the calibrate module is used to set the nodes **120–124** so that the oscillation frequency is adjusted with respect to the base station RF modulation frequency.

Transistors M1–M6 are p-FETs controlled by the voltage VPMR, and the current through each transistor mirrors the current through a standard p-FET elsewhere on the chip. In the operating regime of the circuit of FIG. **5**, the relative current through each transistor **M1–M6** is defined by the geometry of the transistors, as is well known to one skilled in the art of analog integrated circuit design. The currents through transistors M1–M6 are in the ratio 2:1:2:4:8:16 respectively. On the chip, transistors **M1–M6** are implemented as multiple devices of the same size. Thus, the transistor with weight **16** is actually **16** identical transistors connected in parallel. (The transistors have dimensions $w=5\mu\times 1=10\mu$ in a preferred implementation.) The current from current source **104** can thus be set at approximately every integral multiple between 2 and 33 of a base current of approximately 35 nA by appropriate adjustment of voltages on nodes **120–124**. There are thus 32 different tag oscillator frequencies that can be generated by the tag oscillator **100**.

It is clear to one of ordinary skill in the art that more or fewer transistors such as M2–M6 could be used to set more or fewer values of the tag oscillator frequency. It is also clear that the settable frequencies are not necessarily equally distributed through the desired frequency region. It is well within the scope of the invention to have non-integral ratios for the currents from transistors **M1–M6** to provide finer control near the most desired frequency, and yet allow wider excursions from the mean of the allowed frequencies. It is also well within the scope of the invention to reverse the p and n channel circuits shown in the figures with equivalent n and p channel circuits. The circuit shown is preferable, however, in that the current supplies are somewhat more stable in an environment where VDD may shift and where the ground is more stable.

An alternative preferred embodiment of the oscillator section **100** uses a capacitor section **106** with a value of the capacitance set by the calibrate module using voltages on connection **302**. This embodiment is shown in the circuit diagram of FIG. **6** for the capacitor section **106**. In this case, the current source section **104** would preferably comprise one or two p-fet transistors. The digitally controlled capacitor section **106** shown in FIG. **6** runs at the fastest rate when all capacitors C_1–C_5 are switched off from receiving current from the current source section **104**, and the smallest capacitor C_6 is used. In this case, the variations in manufacture of the limited current supply transistors and the capacitance C_6 would lead to unwanted variations in the maximum tag

oscillation frequency. This disadvantage outweighs the advantage that the oscillator draws approximately the same low constant current at all times (although the current used during the transitions may vary greatly with frequency).

An alternative preferred embodiment of the oscillator section **100** uses a comparison voltage in section **108** with a value of the comparison voltage set by the calibrate module using voltages on connection **302**. This embodiment is shown in the circuit diagram of FIG. **7** for the voltage comparator section **108**. In this case, the current source section **104** would preferably be one or two p-fet transistors, and the capacitance section **106** would be a preferably comprise a single capacitor. This circuit works by providing a controllable way to unbalance the current sources which supply the differential pair in the first stage of the comparator. Unbalancing the current sources serves to move the comparator trip point.

The digitally controlled current source section **104** sketched in the circuit of FIG. **5***a* is preferred over the digitally controlled capacitance section **106** or the digitally controlled voltage comparator section **108** sketched in FIGS. **6** and **7** respectively. The current is extremely low when the oscillator frequency is low, and the stability and predictability of the oscillation frequency is not as important as when the frequency is raised for the purposes of tag conmmunication. At the higher tag oscillator frequencies, the current draw is higher, and as a result the frequency is much more stable and predictable and is less affected by manufacturing and tag environmental variations.

Transistor **M70** and capacitor **C69** are optionally included in the oscillator section to slightly slow the oscillator after the oscillation frequency has been set. Thus, the frequency could be set so that there are approximately 9 counts of the clock in every base station modulation frequency interval. **M70** can then be turned on, which will guarantee that there are less than 9 counts per interval.

A preferred comparator section **108** is also shown in FIG. **5***a*. This voltage comparison circuit is well known to one skilled in the art. For example, see page **333** of Allen and Holberg—CMOS Analog Circuit Design (1987).

The optional sharpen and delay module **112** circuit is shown in FIG. **5***b*. While the signal on line **118** could be used as a clock signal for the tag electronics and could be used to discharge capacitor section **106** through transistor **110** if it were connected to line **114**, the slow rise time of signal on line **118** would waste current in the digital gate using it as input. Furthermore, the oscillator output spike might be too narrow.

The series of resettable inverter circuits in the sharpen and delay module **112** shown in FIG. **5***b* serve to delay and sharpen the final pulse applied to line **102**. The delay allows us to perform computations on both rising and falling edges of the oscillator output with adequate intervening setup and hold time. The sharpen and delay circuit is also more broadly required to ensure a wide enough clock pulse width for use by the digital electronics on the chip. The sharpen and delay circuit is innovative in that it works at low current due to the current limited early gain stages. The circuit is also innovative in that it is resettable, in that the delay line is cleared of data when an oscillator reset is requested. When the circuit without resettability was tried, it was not reliable.

FIG. **8** shows a flow chart **800** of a method of implementing and using the apparatus of the invention. In step **805**, the base station sends out a steady, unmodulated "Preamble Detect" signal. In step **810** the base station oscillator section is running with the appropriate voltages set on nodes

120–124 so the tag oscillator runs at the slowest frequency allowable. The tag counter is reset on the rising edge of the base station steady, unmodulated signal, and the tag counter counts the clock pulses on line **102**. The tag counts the pulses until the next edge of the base station signal and compares the tag counter count to a certain preset number, for example, 8. If the tag counter count is greater than 8, the tag decides that the base station is sending a preamble detect signal, and readies itself for the next step. If the number of counts is less than 8 the tag resets the tag counter and begins again to wait for a long enough time t of steady, unmodulated RF. The waiting period prevents the oscillator from calibrating in the middle of a data transmission, as might occur if a tag enters the base station field during base station communication with another tag.

After the base station has sent a steady RF signal for the required length of time in step **805**, the base station in step **815** starts to send a steadily modulated signal where the RF is turned on and off at a frequency f_1. At the rising edge of the first modulated pulse, the tag starts the calibration procedure of step **820**, and for the next N pulses (where N is an integer) of the steadily modulated RF from the base station, the tag sets the calibration of the tag oscillator so that the tag oscillator frequency is set approximately to a certain multiple of the base station modulation frequency f_1. When the base station has sent a sufficient number of pulses in step **815** that the tag has had time to complete step **820**, the base station sends a particular modulation pattern called a "Start Delimiter Code" in step **825**. The start delnimter code optionally contains pulses that are "too long" in that the RF field is "on" for three times as long as would be the case when the base station were sending a steadily modulated RF signal with modulation frequency f_1. This "long pulse" technology is innovative in the field of RF tags. The tag receives the start delimiter code in step **830**, using the start delimiter code to check that that the tag oscillator frequency is indeed set correctly and that the tag is decoding valid base station data. Further, the receipt of the start delimiter code ensures that the tag matches the base station's place in the data stream If the start delimiter code is not received correctly, the tag returns to step **810**. The tag proceeds to the next step **840** of receiving the command sent by the base station. Meanwhile, the base station now transmits command data in step **835**. Such data could be instructions to the tag to write data to the tag memory, to read data from the tag memory and transmit the data to the base station, to set some tag state indicator, or for the tag to perform some other tag function which the particular tag may be able to perform. The tag receives the command data in step **840**, and decides in step **850** on the basis of the command data what to do. If the command data is garbled, the tag cannot understand what to do, and returns to step **810** to wait for another try. If the tag does understand the command data, the tag may write data to the tag memory in step **870** or transmit data to the base station in step **860**, as examples, and then the tag returns to step **810** to await further orders. During the writing of data to the tag memory **870** or transmitting data to the base station step **860**, the base station transmits full power in a steady unmodulated stream of RF power in order to supply power throughout the relatively slow E^2-PROM write operation. (If faster memory elements such as ferroelectric random access memory (FRAM) memory elements are used, the tag may write the memory at the same time as the data is received.) The base station receives any data sent from the tag in step **855** which takes place simultaneously with step **845**, and then takes further action as appropriate.

A flow chart **900** of the method of calibrating the tag oscillator is shown in FIG. **9**. The tag resets the tag oscillator

so that the tag oscillator frequency is the lowest possible frequency in step **910**. In the example given by FIG. **5***a* and FIG. **5***b*, all nodes **120**–**124** would be set high so that only low current charges capacitor section **106**. The most significant bit is then reset to 0 in step **920**. The local counter **200** is reset to zero on the rising edge of the steadily modulated RF field sent out by the base station in step **815** of FIG. **8**. (It is clear to one skilled in the art that falling edges could also be used, or any other regular transitions.) The local counter then counts pulses on line **102** in step **940** until the next rising edge of the steadily modulated RF field sent out from the base station. If the count value is greater than 8 (ie 9 or greater), the decision step **950** sends the system to step **960**, where the last bit which was reset to zero is set back to one. (The oscillator is running too fast, and has to be slowed down. Because the control devices are p-FETs in the embodiment described, a logic level **1** is used to turn them off.). If the count is less than 9, the oscillator is running slow, and the system skips from step **950** to **970** to reset the next significant bit to zero. If all the control bits have not been reset, the system then decides at step **980** to return to step **930** to measure again whether the oscillator is running fast or slow compared to the base station modulation frequency, and the process is repeated in order from the most significant bit to the least significant bit until all nodes **120**–**124** in FIG. **5***a* are set correctly so that the tag oscillator frequency is just under 9 times the base station modulation frequency. Of course, it is clear to one skilled in the art that the count value could be more or less than 8 for the tag to calibrate the tag oscillator with respect to the base station modulation frequency. When all the bits have been reset (and possibly set again to 1), the system moves to step **990** and optionally reduces the tag oscillator frequency so that it is surely less than 9 times the base station modulation frequency.

Throughout the rest of the data stream, the settings on nodes **120**–**124** remain fixed. However, the phase reset signal **116** continues to be generated to maintain synchronization during the base station to tag data transmission.

Note that the phase reset signal **116** is not generated while the tag is writing data to the tag memory or while the tag is transmitting data to the base station. During these operations, the base station transmits unmodulated RF power, and the tag clock section **40** is free running at the calibrated frequency which is determined by the settings on nodes **120**–**124**.

It will be apparent to one skilled in the art that circuits equivalent to those disclosed herein may be used for the purposes stated herein. In particular, the equivalent n-FET and p-FET circuits are anticipated by the inventors.

We claim:

1. A passive radio frequency (RF) transponder (tag) for receiving an RF signal from a base station, comprising;

- a tag antenna for receiving the RF signal fron the base station the RF signal having a carrier frequency;
- a tag rectification power supply connected to the tag antenna;
- a tag logic section and a tag memory section the tag logic section and the tag memory section receiving power only from the tag antenna through the tag rectification power supply;
- a receiver section connected to the tag antenna; and
- a tag oscillator connected to the receiver section, the tag oscillator having a plurality of possible discrete frequencies of oscillation, the tag oscillator having a tag oscillation frequency much less than the carrier frequency, the tag oscillator frequency used to determine a tag modulation frequency of an RF signal backscattered from the tag antenna, the tag oscillation frequency determined by the RF signal sent from the base station.

2. The RF tag of claim **1**, where the RF signal is modulated at a modulation frequency f_1, and the frequency of oscillation of the tag oscillator is determined by f_1.

3. The RF tag of claim **2**, where the RF signal is amplitude modulated at a modulation frequency f_1.

4. The RF tag of claim **2**, where the RF signal is frequency modulated at a modulation frequency f_1.

5. The RF tag of claim **2**, where the RF signal is phase modulated at a modulation frequency f_1.

6. The RF tag of claim **1**, wherein the tag oscillator further comprises;

- a current source section;
- a capacitor section, the capacitor section charged from the current source section;
- a voltage comparator section, the voltage comparator section comparing the voltage across the capacitor section to a preset comparison voltage; and
- a switch, the switch discharging the capacitor section when the voltage across the capacitor section reaches the preset comparison voltage.

7. The RF tag of claim **6**, where the current source section comprises a plurality of defined current sources, at least one of the plurality of defined current sources being controlled to charge the capacitor section in response to the RF signal sent from the base station.

8. The RF tag of claim **7**, where at least one of the defined current sources is a defined current transistor in series with a transistor switch.

9. The RF tag of claim **6**, where the capacitor section source comprises a plurality of capacitances connected in parallel, at least one of the plurality of capacitances being controlled to receive current or not to receive current from the current source section in response to the RF signal sent from the base station.

10. The RF tag of claim **6**, where the comparator section source further comprises a plurality of defined current sources for delivering current to a voltage comparison circuit, at least one of the plurality of defined current sources being controlled to deliver current in response to the RF signal sent from the base station.

11. The RF tag of claim **1**, where the tag oscillator uses less than 500 microamperes of current.

12. The RF tag of claim **11**, where the tag oscillator uses less than 1 microampere of current.

13. A method of setting a tag oscillation frequency of a tag oscillator of a passive RF tag comprising;

a) receiving an RF signal from a base station, and;

b) adjusting the tag oscillation frequency in response to the RF signal from the base station, wherein the tag oscillation frequency is much less than a carrier frequency of the RF signal, and wherein the tag oscillation frequency is used to determine a tag modulation frequency of an RF signal backscattered from the tag.

14. The method of setting an oscillation frequency of claim **13**, where the RF signal is modulated at a modulation frequency f_1 and the oscillation frequency is set as a function of f_1.

15. The method of claim **14**, where the RF signal is amplitude modulated at a modulation frequency f_1.

16. The method of claim **14**, where the RF signal is frequency modulated at a modulation frequency f_1.

17. The method of claim **14**, where the RF signal is phase modulated at a modulation frequency f_1.

18. The method claim 14, where the tag counts the number of tag oscillator pulses in one period of the base station modulation frequency, and adjusts tag oscillator frequency so that the number is approximately equal to a preset number.

19. A method of setting an oscillation frequency of a tag oscillator of a passive RF tag, where the tag adjusts the oscillator frequency according to the following steps;

a) setting the tag oscillator so that the tag oscillation frequency is the lowest possible frequency by setting all control bits equal to one;

b) resetting the most significant bit equal to zero;

c) resetting a local counter of tag oscillator pulses on a rising edge of the steadily modulated RF field sent out by the base station;

d) counting pulses of the tag oscillator until the next rising edge of the steadily modulated RE field sent out from the base station;

e) if the count value is greater than a preset number, resetting the local counter, setting the last bit reset to one, resetting the next significant bit to zero, and returning to step (c);

f) if the count value is less than the preset number, resetting the local counter, resetting the next significant bit to zero, and returning to step (c); and

g) continuing until all control bits have been set or reset and the count value is approximately equal to the preset number.

20. The method claim 19, where the tag further adjusts the oscillator frequency in the additional step;

h) slowing the tag oscillator so that the count value is definitely less than the preset number, and definitely more than the preset number minus one.

21. The method claim 19, where the tag further adjusts the tag oscillator in the additional step of; resetting the tag oscillator phase on the rising edge of the steadily modulated RF field sent out by the base station.

22. A system for sending and receiving modulated RF signals, comprising;

a base station for sending modulated RF signals, the RF signals having a carrier frequency; and

at least one passive RF tag for receiving the RF signals, the RF tag comprising a tag antenna for receiving the RF signal from the base station, a tag receiver section connected to the tag antenna; and a tag oscillator connected to the tag receiver section, the tag oscillator having a tag oscillation frequency much less than the carrier frequency, the tag oscillation frequency used to determine the a modulation frequency of an RF signal backscattered from the tag antenna, the tag oscillator frequency determined by the Rf signals sent by the base station.

23. The system of claim 22, where the base station sends RF signals modulated at a modulation frequency f_1, and the frequency of oscillation of the tag oscillator is determined by the modulation frequency f_1.

24. The system of claim 23, where the RF signal is amplitude modulated at a modulation frequency f_1.

25. The system of claim 23, where the RF signal is frequency modulated at a modulation frequency f_1.

26. The system of claim 23, where the RF signal is phase modulated at a modulation frequency f_1.

27. The system of claim 22, where the base station further comprises a computer for receiving and sending data from and to the tag.

28. A passive radio frequency (RF) transponder (tag) for receiving an RF signal from a base station, comprising;

a tag antenna for receiving the RF signal from the base station, the RF signal having a carrier frequency;

a receiver section connected to the tag antenna;

a tag rectification power supply connected to the tag antenna;

a tag logic section and a tag memory section, the tag logic section and the tag memory section receiving power only from the tag antenna through the tag rectification power supply; and

a tag oscillator connected to the receiver section, the tag oscillator having a tag oscillation frequency much less than the carrier frequency, the tag oscillation frequency used to determine a tag modulation frequency of an RF signal backscattered from the tag antenna, the tag oscillation frequency determined by the RF signal sent from the base station.

* * * * *

EXHIBIT C

US005995019A

United States Patent [19]

Chieu et al.

[11] Patent Number: 5,995,019

[45] Date of Patent: *Nov. 30, 1999

[54] **METHOD FOR COMMUNICATING WITH RF TRANSPONDERS**

[75] Inventors: **Trieu Can Chieu**, Scarsdale; **Thomas Anthony Cofino**, Rye; **Harley Kent Heinrich**, Brewster, all of N.Y.; **Paul Jorge Sousa**, Peabody, Mass.; **Li-Cheng Richard Zai**, Ossining, N.Y.

[73] Assignee: **Intermec I.P. Corp**

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/111,096**

[22] Filed: **Jul. 6, 1998**

Related U.S. Application Data

[63] Continuation of application No. 08/720,598, Sep. 30, 1996, Pat. No. 5,777,561.

[51] **Int. Cl.**[6] **H04Q 1/00**

[52] **U.S. Cl.** **340/825.54**; 342/42

[58] **Field of Search** 340/825.54, 572.1, 340/825.52; 342/42

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5,410,315	4/1995	Huber	342/42
5,550,547	8/1996	Chan	342/42
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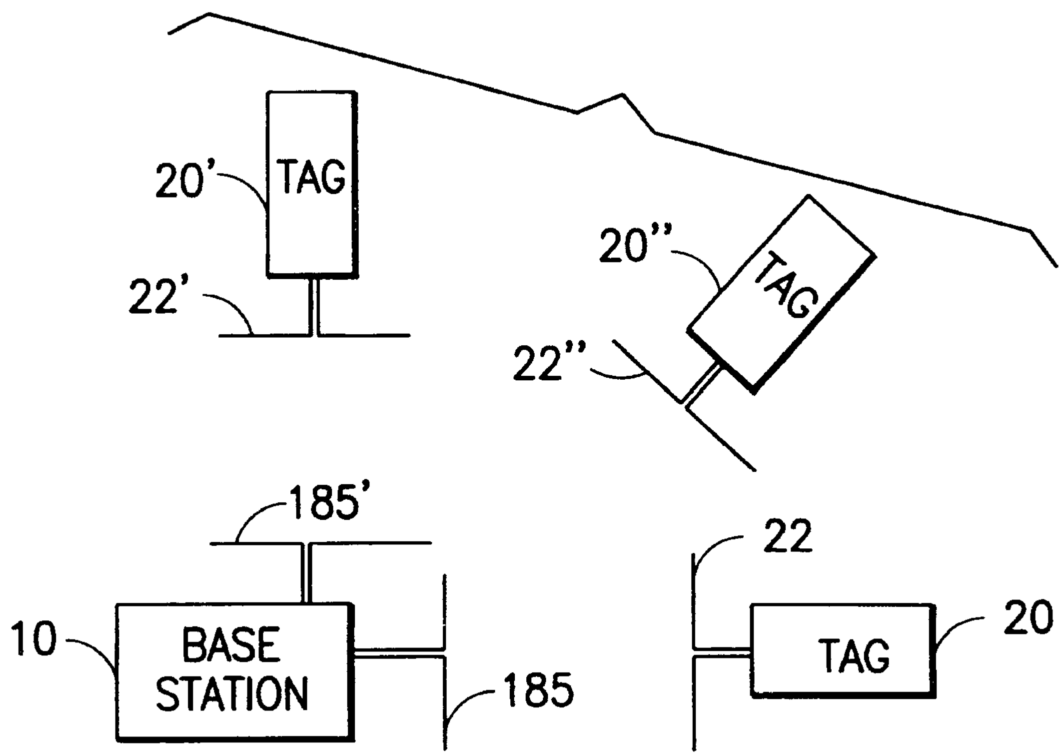
Primary Examiner—Brian Zimmerman
Attorney, Agent, or Firm—R.T. Hodgson

[57] **ABSTRACT**

A method of selecting groups of radio frequency RF transponders (tags) for communication between a base station and the tags. The tags are selected into groups according to a physical attribute of the signal sent by the tags to the base station, or according to the physical response of the tags to a physical attribute of the signal sent from the base station to the tags. Communication with the tags is thereby simplified, and the time taken to communicate with the first tag is markedly reduced.

18 Claims, 7 Drawing Sheets



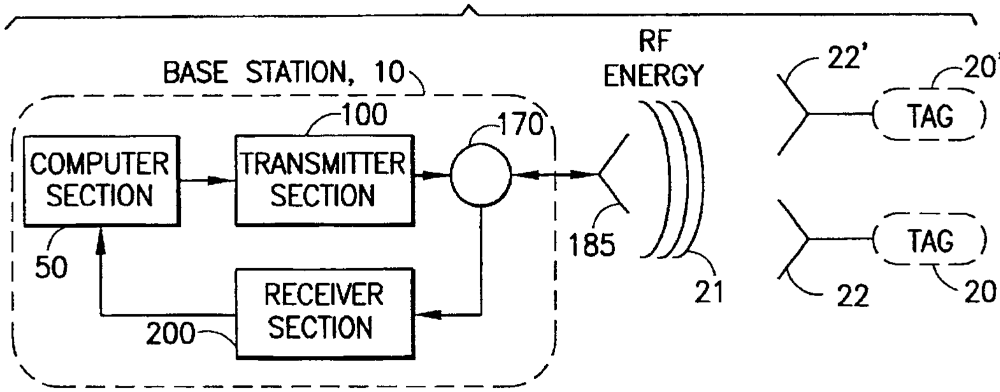


FIG.1

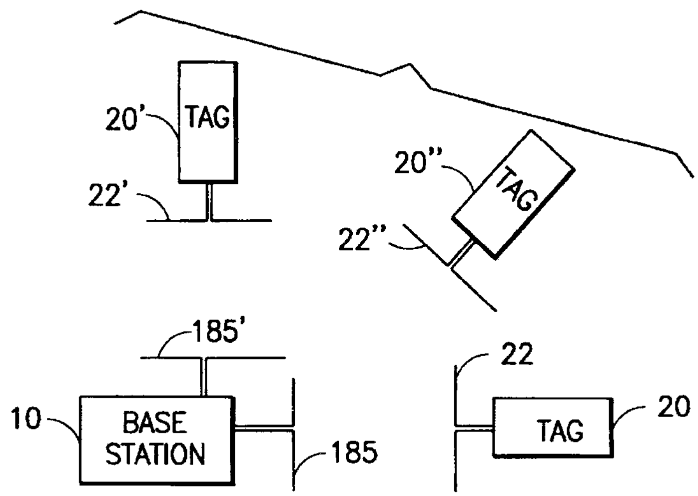


FIG.2

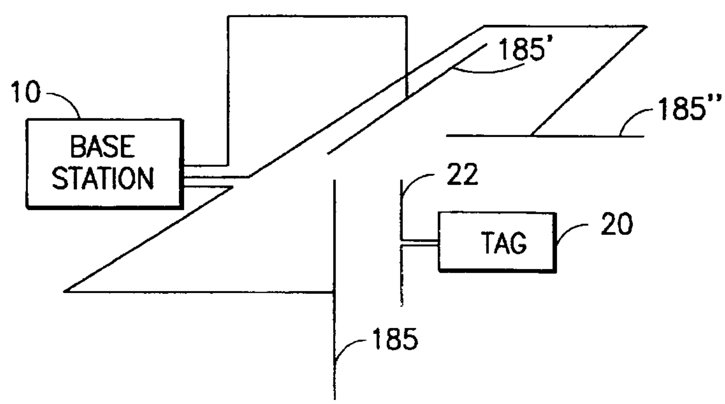


FIG.3

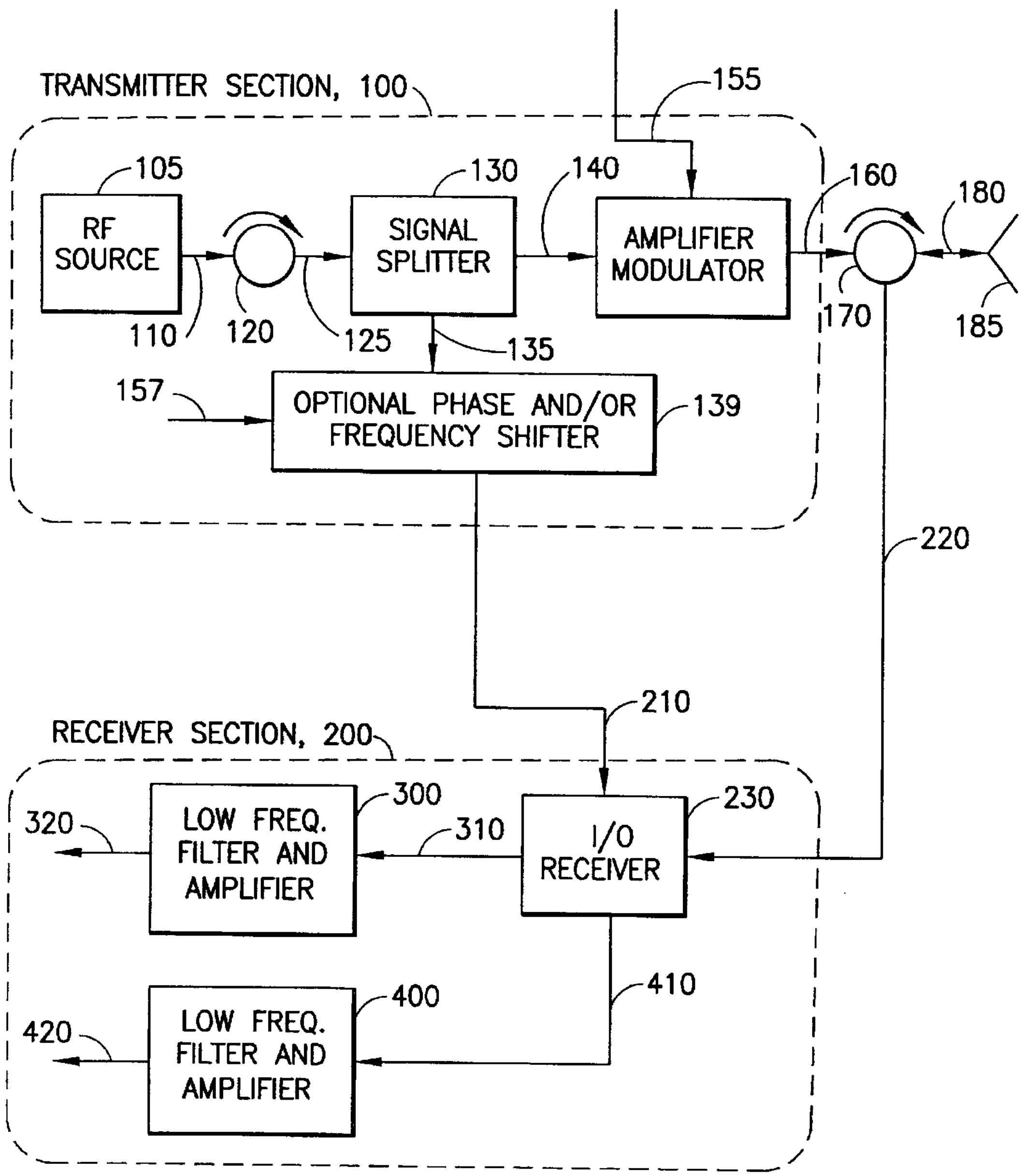

TRANSMITTER SECTION, 100
155
105
RF SOURCE
130
SIGNAL SPLITTER
140
AMPLIFIER MODULATOR
160
180
110
120
125
135
170
185
157
OPTIONAL PHASE AND/OR FREQUENCY SHIFTER
139
220
210
RECEIVER SECTION, 200
320
LOW FREQ. FILTER AND AMPLIFIER
300
310
I/O RECEIVER
230
410
420
LOW FREQ. FILTER AND AMPLIFIER
400

FIG.4

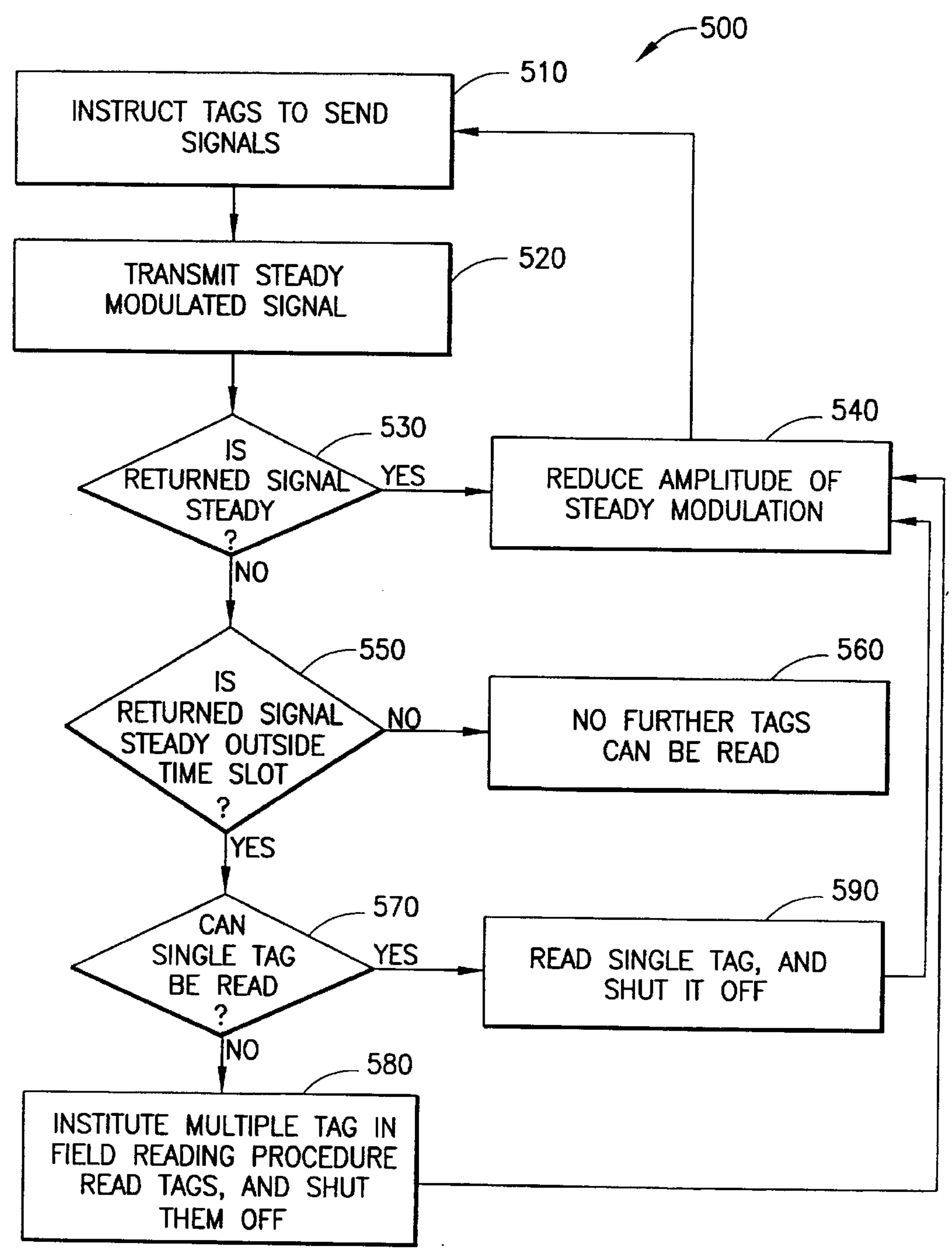
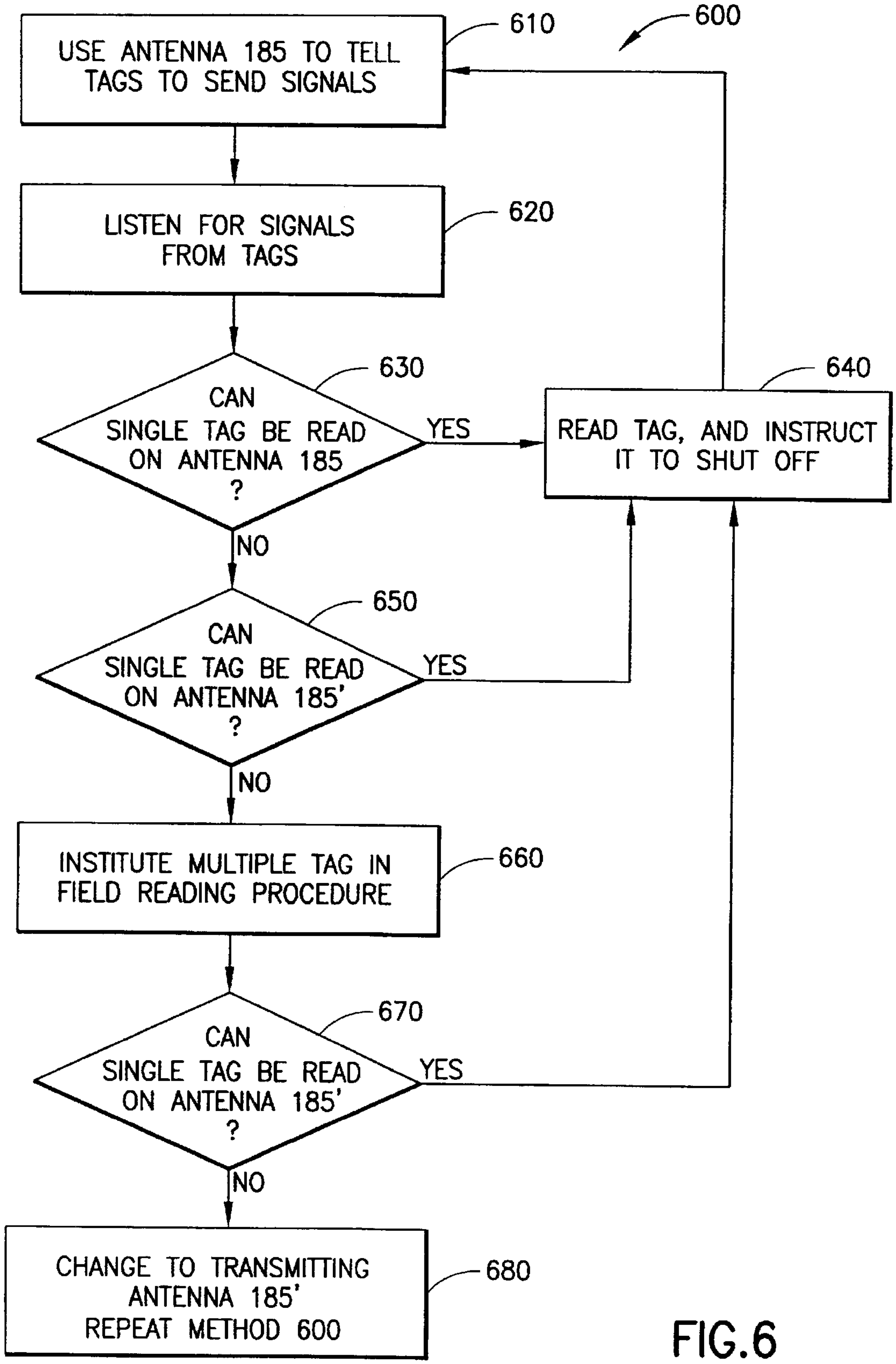

500
510
INSTRUCT TAGS TO SEND SIGNALS
520
TRANSMIT STEADY MODULATED SIGNAL
530
IS RETURNED SIGNAL STEADY ?
YES
NO
540
REDUCE AMPLITUDE OF STEADY MODULATION
550
IS RETURNED SIGNAL STEADY OUTSIDE TIME SLOT ?
NO
YES
560
NO FURTHER TAGS CAN BE READ
570
CAN SINGLE TAG BE READ ?
YES
NO
590
READ SINGLE TAG, AND SHUT IT OFF
580
INSTITUTE MULTIPLE TAG IN FIELD READING PROCEDURE READ TAGS, AND SHUT THEM OFF

FIG.5



600
USE ANTENNA 185 TO TELL TAGS TO SEND SIGNALS
610
LISTEN FOR SIGNALS FROM TAGS
620
CAN SINGLE TAG BE READ ON ANTENNA 185 ?
630
YES
NO
READ TAG, AND INSTRUCT IT TO SHUT OFF
640
CAN SINGLE TAG BE READ ON ANTENNA 185' ?
650
YES
NO
INSTITUTE MULTIPLE TAG IN FIELD READING PROCEDURE
660
CAN SINGLE TAG BE READ ON ANTENNA 185' ?
670
YES
NO
CHANGE TO TRANSMITTING ANTENNA 185' REPEAT METHOD 600
680

FIG.6

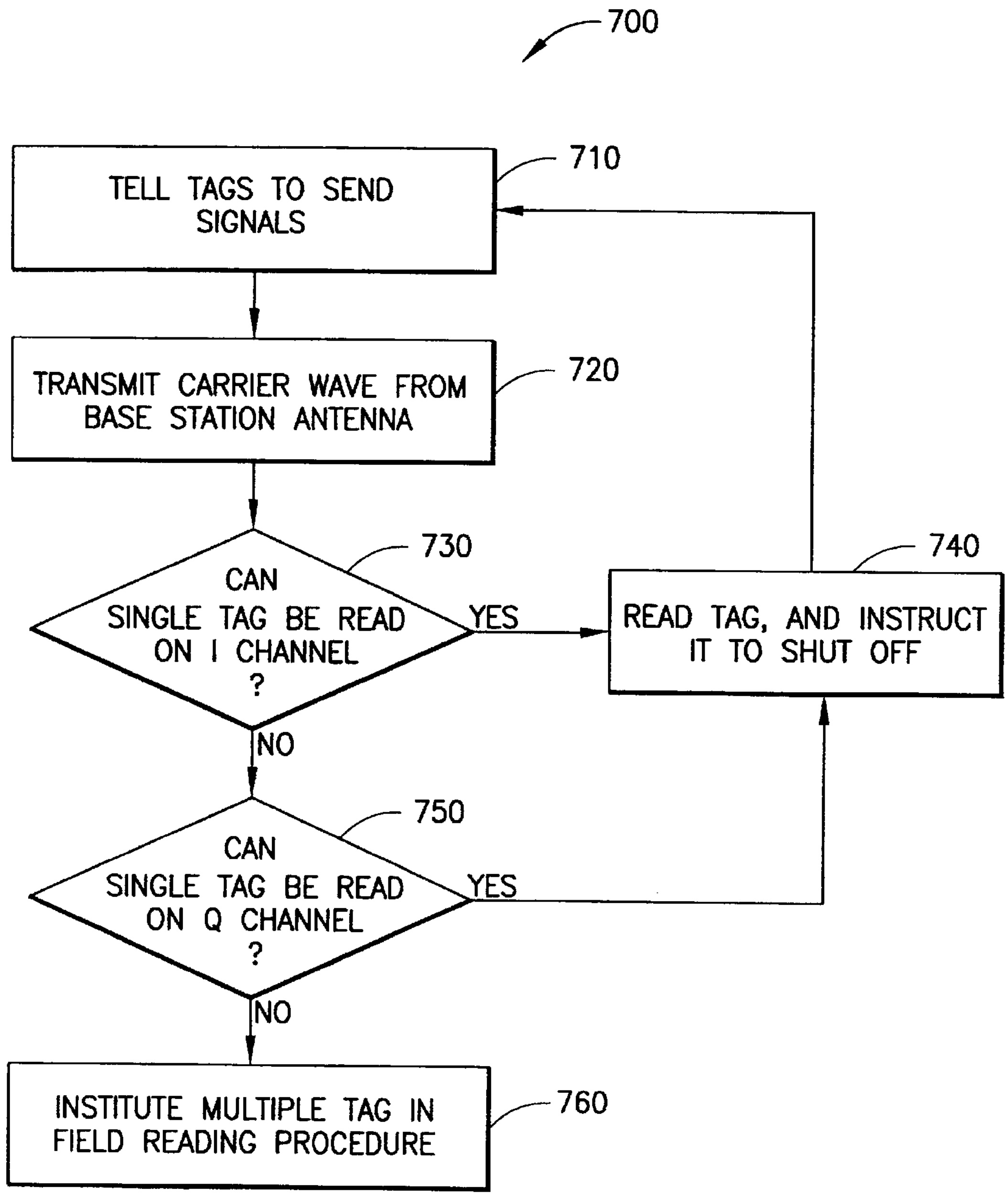
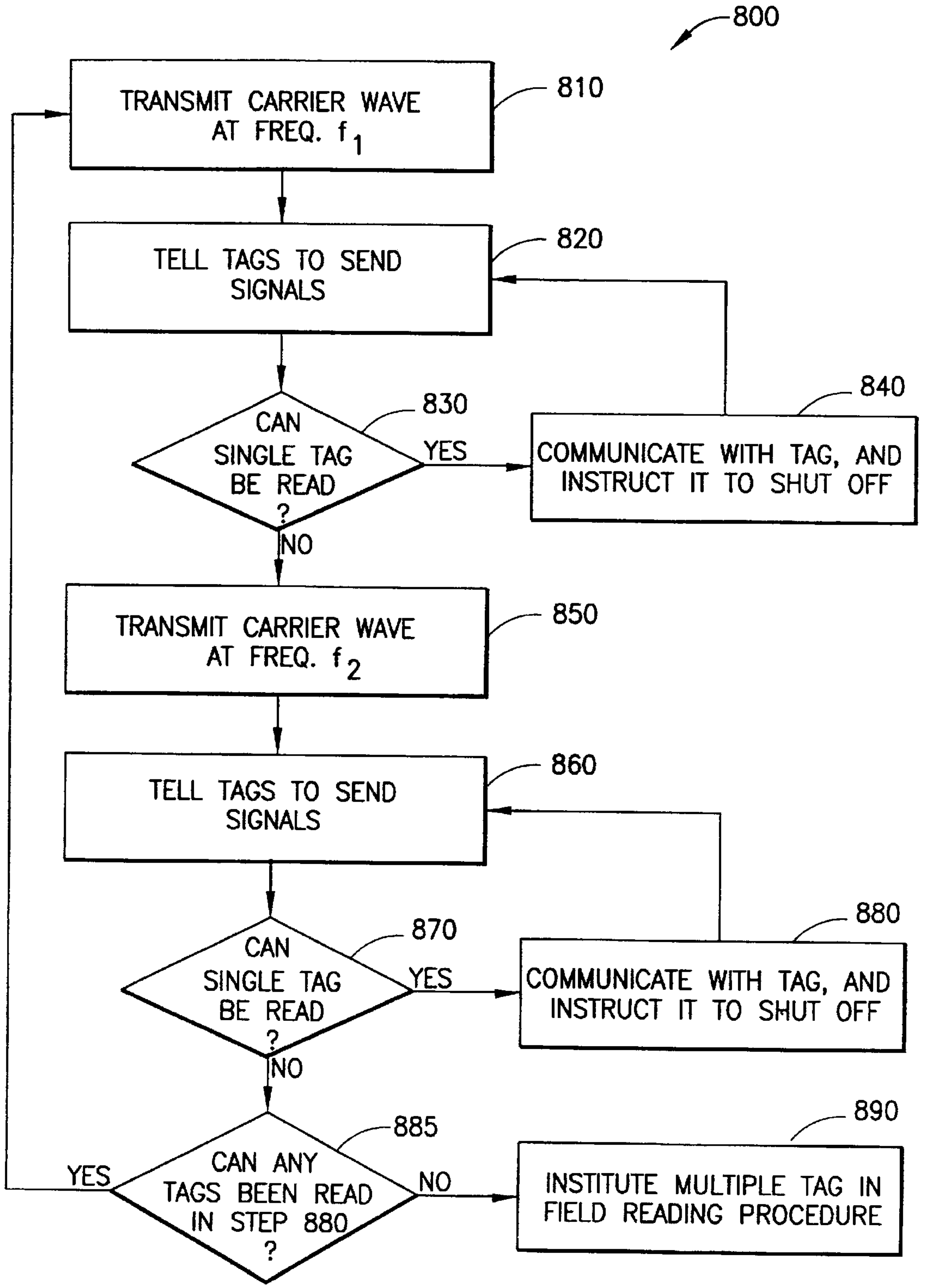
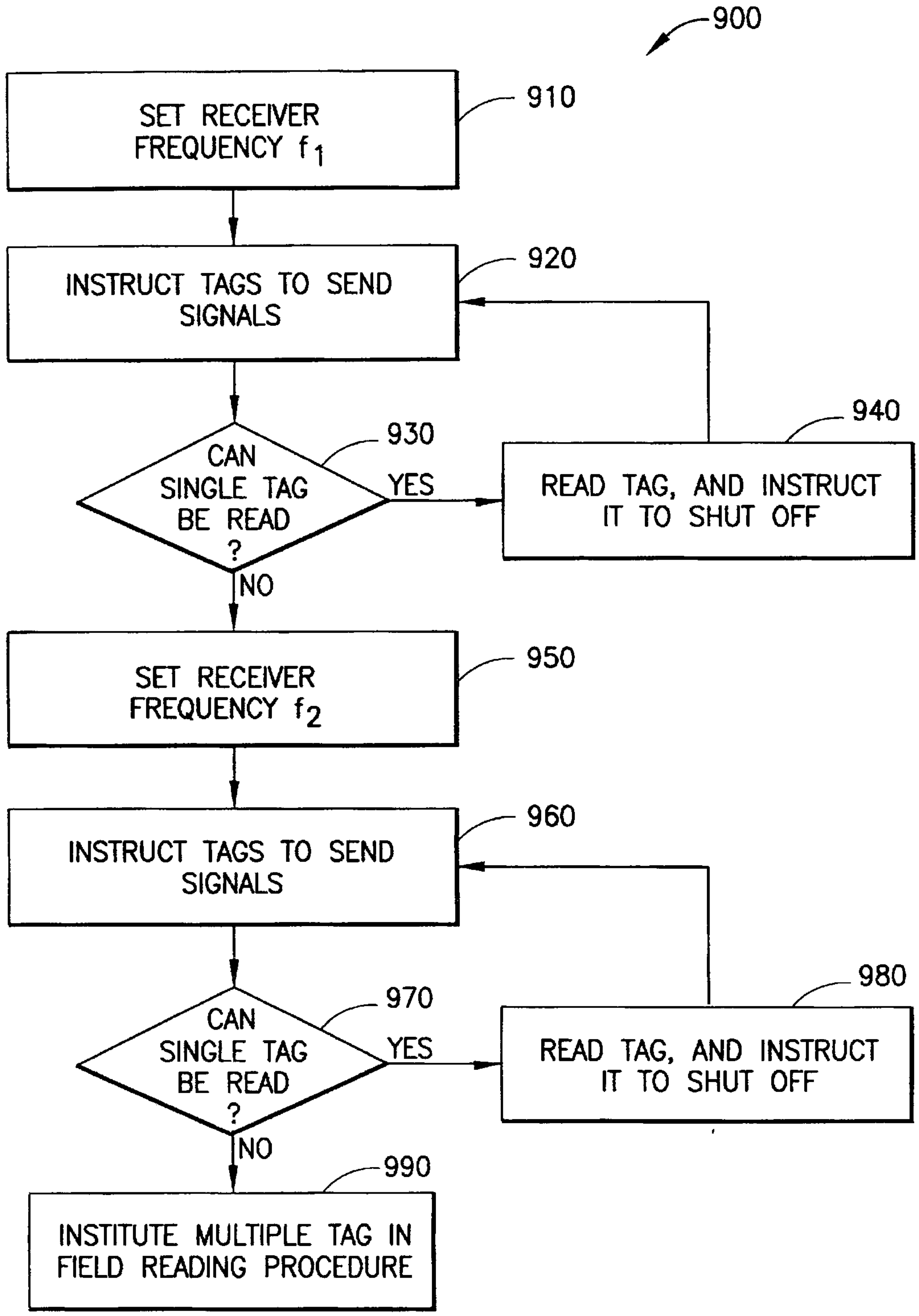

700
TELL TAGS TO SEND SIGNALS
710
TRANSMIT CARRIER WAVE FROM BASE STATION ANTENNA
720
CAN SINGLE TAG BE READ ON I CHANNEL ?
730
YES
NO
READ TAG, AND INSTRUCT IT TO SHUT OFF
740
CAN SINGLE TAG BE READ ON Q CHANNEL ?
750
YES
NO
INSTITUTE MULTIPLE TAG IN FIELD READING PROCEDURE
760

FIG.7



800
TRANSMIT CARRIER WAVE AT FREQ. f_1
810
TELL TAGS TO SEND SIGNALS
820
CAN SINGLE TAG BE READ ?
830
YES
NO
COMMUNICATE WITH TAG, AND INSTRUCT IT TO SHUT OFF
840
TRANSMIT CARRIER WAVE AT FREQ. f_2
850
TELL TAGS TO SEND SIGNALS
860
CAN SINGLE TAG BE READ ?
870
YES
NO
COMMUNICATE WITH TAG, AND INSTRUCT IT TO SHUT OFF
880
CAN ANY TAGS BEEN READ IN STEP 880 ?
885
YES
NO
INSTITUTE MULTIPLE TAG IN FIELD READING PROCEDURE
890

FIG.8



900
SET RECEIVER FREQUENCY f_1
910
INSTRUCT TAGS TO SEND SIGNALS
920
CAN SINGLE TAG BE READ ?
930
YES
NO
READ TAG, AND INSTRUCT IT TO SHUT OFF
940
SET RECEIVER FREQUENCY f_2
950
INSTRUCT TAGS TO SEND SIGNALS
960
CAN SINGLE TAG BE READ ?
970
YES
NO
READ TAG, AND INSTRUCT IT TO SHUT OFF
980
INSTITUTE MULTIPLE TAG IN FIELD READING PROCEDURE
990

FIG.9

METHOD FOR COMMUNICATING WITH RF TRANSPONDERS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 08/720,598, filed Sep. 30, 1996, now U.S. Pat. No. 5,777, 561, issued Jul. 7, 1998.

FIELD OF THE INVENTION

The field of the invention is the field of Radio Frequency (RF) Transponders (RF Tags), wherein a Base Station sends power and information to one or more RF Tags which contain logic and memory circuits for storing information about objects, people, items, or animals associated with the RF Tags. The RF Tags can be used for identification and location (RID Tags) of objects and to send information to the base station by modulating the load on an RF Tag antenna.

BACKGROUND OF THE INVENTION

RF Tags can be used in a multiplicity of ways for locating and identifying accompanying objects, items, animals, and people, whether these objects, items, animals, and people are stationary or mobile, and transmitting information about the state of the of the objects, items, animals, and people. It has been known since the early 60's in U.S. Pat. No. 3,098,971 by R. M. Richardson, that electronic components on a transponder could be powered by radio frequency (RF) power sent by a "base station" at a carrier frequency and received by an antenna on the tag. The signal picked up by the tag antenna induces an alternating current in the antenna which can be rectified by an RF diode and the rectified current can be used for a power supply for the electronic components. The tag antenna loading is changed by something that was to be measured, for example a microphone resistance in the cited patent. The oscillating current induced in the tag antenna from the incoming RF energy would thus be changed, and the change in the oscillating current led to a change in the RF power radiated from the tag antenna. This change in the radiated power from the tag antenna be picked up by the base station antenna and thus the microphone would in effect broadcast power without itself having a self contained power supply. In the cited patent, the antenna current also oscillates at a harmonic of the carrier frequency because the diode current contains a doubled frequency component, and this frequency can be picked up and sorted out from the carrier frequency much more easily than if it were merely reflected. Since this type of tag carries no power supply of its own, it is called a "passive" tag to distinguish it from an active tag containing a battery. The battery supplies energy to run the active tag electronics, but not to broadcast the information from the tag antenna. An active tag also changes the loading on the tag antenna for the purpose of transmitting information to the base station.

The "rebroadcast" of the incoming RF energy at the carrier frequency is conventionally called "back scattering", even though the tag broadcasts the energy in a pattern determined solely by the tag antenna and most of the energy may not be directed "back" to the transmitting antenna.

In the 70's, suggestions to use tags with logic and read/write memories were made. In this way, the tag could not only be used to measure some characteristic, for example the temperature of an animal in U.S. Pat. No. 4,075,632 to Baldwin et. al., but could also identify the animal. The antenna load was changed by use of a transistor.

Prior art tags have used electronic logic and memory circuits and receiver circuits and modulator circuits for receiving information from the base station and for sending information from the tag to the base station.

The continuing march of semiconductor technology to smaller, faster, and less power hungry has allowed enormous increases of function and enormous drop of cost of such tags. Presently available research and development technology will also allow new function and different products in communications technology.

U.S. Pat. No. 5,214,410, hereby incorporated by reference, teaches a method for a base station to communicate with a plurality of Tags . The tags having a particular code are energized, and send a response signal at random times. If the base station can read a tag unimpeded by signals from other tags, the base station interrupts the interrogation signal, and the tag which is sending and has been identified shuts down. The process continues until all tags in the field have been identified. If the number of possible tags in the field is large, this process can take a very long time. The average time between the random responses of the tags must be set very long so that there is a reasonable probability that a tag can communicate in a time window free of interference from the other tags.

RELATED APPLICATIONS

Copending patent applications assigned to the assignee of the present invention and hereby incorporated by reference, are:

Ser. No. 08/303,965, filed Sep. 9, 1994 entitled RF Group Select Protocol, by Cesar et al, now U.S. Pat. No. 5,670,037;

Ser. No. 08/304,340, filed Sep. 9, 1994 entitled Multiple Item RF ID protocol, by Chan et al, now U.S. Pat. No. 5,550,547;

Ser. No. 08/521,898, filed Aug. 31, 1995 entitled Diode Modulator for RF Transponder by Friedman et al, now U.S. Pat. No. 5,606,323;

application submitted Aug. 9, 1996, entitled RFID System with Broadcast Capability by Cesar et al; and

application submitted Jul. 29, 1996 entitled RFID transponder with Electronic Circuitry Enabling and Disabling Capability, by Heinrich et al.

These applications teach a communications protocol whereby a base station communicates to a plurality of tags by polling the tags and shutting down tags in turn until there is just one left The information is then exchanged between the base station and the one tag, and then the one tag is turned off. The unidentified tags are then turned on, and the process is repeated until all the tags have the communication protocol completed. Typical protocols requires a time which is not linearly proportional to the number of tags in the field More tags take a longer time per tag than fewer tags. If the tags can be selected into groups in some way, each group can be dealt with in a shorter time per tag, and the time taken to communicate with the first tag is markedly shortened.

SUMMARY OF THE INVENTION

The method of the present invention is a method of selecting groups of RF tags for a communication protocol comprising selecting a plurality of groups of tags according to a physical attribute of the signal sent by the tags to the base station, or selecting the groups according to the physical response of the tags to a physical attribute of the signal sent from the base station to the tags, and communicating

with the tags in each group. A single tag may be a member of one or more groups. Some groups may have no members. The most preferred embodiment of the invention is the method of selecting groups on the basis of the physical signal strength of the RF signal received from the tags by the base station. The tags have greater or less received signal strength depending on the distance to the base station antenna, the relative orientation of the tag and the base station antennas, and the local conditions of reflectors and absorbers of radiation around the tag. The base station may also select groups of tags according to the polarization or the phase of the returned RF signal, the RF carrier or Doppler shifted RF carrier or modulation frequency sent by the tags, or any another physical signal from the tags. The base station may also select groups of tags according to the physical response of the tags to the polarization, phase, carrier frequency, modulation frequency, or power of the RF signal sent by the base station. The communication protocol can be carried out simultaneously or sequentially with the selected groups. The physical characteristics used to group the tags can be measured simultaneously or sequentially. Different groups may be selected by taking the union, the intersection, or other combinations of the various groups of tags selected according to the different physical attributes. The tag group selection parameters may also include selecting groups by software, i.e. by selecting the groups according to information stored on the tag.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a generalized diagram of a base station communicating to one or more tags.

FIG. **2** is a diagram of a base station having two antennas for receiving information about the polarization of the signal sent by a tag.

FIG. **3** is a diagram of a base station having three antennas for receiving information about the polarization and phase position of the signal sent by a tag.

FIG. **4** is a diagram of a base station circuit which can select the strongest signals from signals sent by a plurality of tags.

FIG. **5** is a flow chart of the most preferred embodiment of the invention.

FIG. **6** is a flow chart of a preferred embodiment of the invention.

FIG. **7** is a flow chart of a preferred embodiment of the invention.

FIG. **8** is a flow chart of a preferred embodiment of the invention.

FIG. **9** is a flow chart of a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** sketches abase station **10** sending RF energy **21** and information to one or more tags **20**. The tags **20** may have varying distances from the base station, and the tag antennas **22** may be in any orientation with respect to the base station antenna. The base station comprises a transmitter section **100**, a computer section **50**, a circulator **170**, a receiver section **200**, and one or more antennas **185**.

FIG. **2** depicts a base station **10** which can group the tags **20** into groups on the basis of polarization of the RF radiation back scattered to the base station **10**. The base station **10** has two perpendicular antennas **185** and **185'** communicating with three tags **20, 20'**, and **20"**. The antennas **185** and **185'**, and **22, 22'** and **22"** are depicted as simple dipole antennas which transmit linearly polarized radiation with the polarization substantially parallel to the antennas. In the diagram shown, antenna **185** may communicate well with the tag **20** having an antenna **22** parallel to antenna **185**, less well with the antenna **22"** which is shown having a 45 degree orientation with respect to antenna **185**, and not at all with the tag with a perpendicular antenna **22'**. The groups are first selected on the a basis of the response of the tags to the polarization of the signal sent out from the base station. In this example, two groups are selected: those tags which respond to the particular polarization, and those tags which do not respond. In the embodiment depicted in FIG. **2**, a signal sent out from antenna **185** brings responses from tag **20** and from tag **20"** to antenna **185**, and from tag **20"** alone to antenna **185'**. The tag antenna **22'** may not receive power from the perpendicular antenna **185**, and so tag **20'** remains silent. The tags are then further selected into subgroups according to the polarization of the returned signal. Thus, three groups of tags are selected by this method in this example, tag **20'** is in one group of "silent" tags, tag **20"** is in the group which is picked up by antenna **185'** because the polarization of the signal from tag **20"** can be detected by antenna **185'**, and tags **20** and **20"** are in the group with polarization components which may be picked up by antenna **185**. Communication with each of the two "non silent" groups in turn or in parallel simplifies and speed the communication protocol. In particular, the time taken to communicate with the first tag is markedly reduced. In the example given above, the signal returned to antenna **185'** is the signal from only a single tag **20"**, and that tag can return the tag identification number while the antenna **185** receives signal signifying more than one tag in the field. The tag **20"** may then be turned off for the duration of the communication procedure, and the process repeated to identify and shut down tag **20**. The sending antenna is then switched to antenna **185'**, and the remaining tag **20'** is identified. While a linear polarization scheme is shown as an example, it is clear to one skilled in the art that circularly polarized signals could also be used with good effect. The exact orientations of the antennas are also not critical to the invention, as long as there is a difference in the sensitivity of the antennas to the polarization of the RF signals sent by the tags. A single base station antenna could be used, as long as the polarization characteristics of the single base station antenna could be changed by the base station or by other means.

FIG. **3** shows a base station **10** with more than two dipole antennas **185, 185'**, and **185"**. In this example, each antenna axis is mutually orthogonal so that the orientation of the linearly polarized backscattering from dipole antennas **22** in the field can be measured and the tags selected into groups for the communication procedure.

FIG. **4** shows a block diagram for circuitry which can allow the base station to select a group of tags by the signal strength received at the base station. The equipment for implementing the method of the most preferred embodiment of the invention uses five sections of the base station **10**: a computer section **50**, a transmitter section **100**; a receiver section **200**; a hybrid coupling device **170**; and an antenna **185**. The computer section may be a relatively unsophisticated circuit for controlling the transmitter and for receiving signals from the receiver, or it could include highly sophisticated workstations for interrogating and writing information to the tags. The transmitter section **100**, under control of the computer section **50**, sends a signal of the appropriate amplitude and frequency (which may or may not be modulated) to the hybrid **170**, which sends the (modulated)

signal to the antenna **185**. The preferred modulation for communication to and from the tags is amplitude modulation, but it may be either frequency or phase modulation. The antenna **185** both sends out the RF carrier frequency which may or may not be modulated, and captures the signals radiated by the tags **20**. The antenna **185** captures the signals radiated by the tags and sends the signals back to the hybrid **170**, which sends the signals to the receiver section **200**. The receiver section down converts and extracts the modulated signal from the carrier, and converts all the modulation energy it receives to a baseband information signal at its output. In the most preferred embodiment, the receiver has two outputs in quadrature called I (in phase with the transmitted carrier) and Q (quadrature, 90 degrees out of phase with the carrier). However, various embodiments of the invention have just one output. The hybrid element **170** connects the transmitter and receiver to an antenna while simultaneously isolating the transmitter and the receiver from each other. That is, the hybrid allows the antenna to send out a strong signal from the transmitter while simultaneously receiving a weak backscattered reflection. The strong transmitted signals being sent into the antenna must be eliminated from the receiver by the hybrid.

The transmitter section depicted by block **100** provides the energy and frequency signals for the transmitter carrier and the receiver down converter, and the amplified and modulated signal **160** which may be sent by the antenna **185**. The RF source **105** of signal **110** is usually isolated by an element **120** between the carrier signal source **105** and the rest of the circuit which avoids coupling problems of coupling reflections back to the RF source. The isolation element **120** is usually a circulator with one port terminated by a resistor. The isolated carrier signal **125** is split into two paths in a signal splitter element **130**. Most of the energy **140** goes to an amplifier modulator element **150**, while signal **135** takes a small signal to the receiver section depicted by block **200**. An optional phase and/or frequency shifter element **139** may be included between the signal splitter **130** and the receiver section **200** to provide control by the computer section **50** over line **157** of the reference phase and frequency signal **210** which the receiver section uses in detecting the signals from the tags. The phase and or frequency shifter **139** may send out signals differing by a small amount in frequency from the signal **110** sent out from the RF source **105**, or it may send out harmonics of the signal. In the amplifier modulator section **150**, the carrier frequency is amplified and modulated by a signal **155** controlled by computer section **50**. A preferred embodiment has a carrier frequency greater than 400 MHZ. A more preferred embodiment has a carrier frequency greater than 900 MHZ. The most preferred embodiment uses a carrier frequency of from 2.3 to 2.5 Ghz, and this signal is amplitude modulated at 20–60 kHz. In the preferred embodiment, a direct modulation of the carrier frequency is depicted However, an up converter of multiple frequencies may also be used. This modulated signal **160** enters the hybrid element **170** and is passed over lead **180** to the antenna **185**. A modulator signal is applied at **155** into the modulator **150** to give a modulation which may be amplitude, frequency or phase modulation. The most preferred embodiment is amplitude modulation.

In the receiver section **200**, the received signal from the antenna **185** travels along lead **180** and enters the hybrid **170** which directs the signal along **220** to the receiver section depicted by block **200**. This signal comprises signals sent by the tags, which modulate the carrier frequency at a frequency of; for example, 40 KHz, and the reflected unmodulated transmitter carrier signal reflected from the antennas or other reflectors in the field. The antenna will never be perfectly matched to the transmitter, and will reflect a signal which is about 20 dB down from the signal transmitted by the antenna. Of course, the carrier signals reflected by the tags, and the various reflections of the transmitted signal, will be much weaker than the signal transmitted from the antenna. The receiver structure **230** of the most preferred embodiment here is a direct down conversion I and Q system where the mixing frequency signal **210** is generated by the source **105** and is the only send-out by the transmitter. The single down conversion system receiver removes the carrier frequency signal and generates two baseband signals which have frequencies in the 40 KHz region in quadrature **310** and **410**. These signals are filtered and amplified by means of signal processing in elements **300** and **400**. The signals **320** and **420** are passed to the computer section **50** for further processing.

The hybrid component **170** is typically a circulator. It passes signals from 160 to 180, from 180 to 220, from 220 to 160 but not the other way around. Hence the transmitter is isolated from both the small amount of modulated carrier reflected by the antenna **185** (20 dB down typically) and the circulator (20 dB leakage typically). The receiver is isolated from the large signal sent from the transmitter **100** to the antenna **185**, and receives about −20 dB signal from leakage from the circulator 170 and a further −20 dB of signal from the reflection from the antenna.

Of course, when the base station modulates the carrier signal to transfer information from the base station to the tags, the reflected modulated signals from the antenna and the leakage from the circulator will swamp out any signals sent by the tags. In the prior art the tags communicate in a time period when there is no modulation of the carrier signal transmitted from the base station, or the tags communicate at a different carrier frequency than that transmitted by the base station, so that the receiver can pick out the modulated signals from the tags from all the reflections and leakages of the carrier signals. The present invention allows simple discrimination of signals by the tag to the base station sent as modulation of the base station carrier frequency, or as modulations of another frequency, from one or more tags, and allows the tags to be sorted in groups determined by the tag signal strength received at the base station.

The most preferred embodiment of the present invention is a method to sort the tags into groups by sending a steady, weak signal modulation at the communication modulation frequency to the tags in the time period where the prior art sends an unmodulated carrier signal so that the tags may communicate back to the base station. The steady, weak modulation frequency is not strong enough to influence the tag, but is strong enough so that the steady, weak modulated signals reflected from the antenna **185** and leaked around the hybrid **170** can be measured by the receiver and can be used to set a level for discriminating amongst the tag signals. In the most preferred embodiment, the communication to the tags is carried out by a 100% amplitude modulation of the carrier frequency at a 20–60 Khz frequency. The preferred protocol for the tags to detect such information is a 50 dB on/off ratio, but this is not necessary to the invention. Any modulation of the carrier frequency which can conceivably be used for communication between the tags and the base station can be used. Such modulations as frequency modulation and phase modulation are well known in the art. In the present invention, a modulation amplitude less than that used to communicate with the tags is impressed on the outgoing carrier wave. The mismatch at the antenna will

always cause that signal to be reflected and to be present at the receiver. This signal is detected at the receiver and is used to establish a deterministic signal floor. As backscattered modulated signals are received and are stronger than this coupling signal, the received back scattered signal dominates the receiver. Hence, a high sensitivity receiver may be used with a forced coupled modulation from the transmitter as its signal noise floor, and behave in a predictable manner between the conditions of no tags in the field, a single tag in the field, multiple tags in the field, and interference. Furthermore, by varying the modulation strength of the weak, modulated signal, the returned signal strength of signals from the tags required to overcome the coupled modulator signal is increased or decreased thereby allowing the base station to select a group of tags based on the returned signal strength.

FIG. **5** depicts a flow chart **500** of the most preferred method for selecting groups of tags and communicating with the tags in each group. A modulation frequency of 40 Khz is chosen as an example. At step **510**, the base station transmits a modulated signal to the base station antenna, and hence to the tags, instructing the tags to respond and return a modulated signal in a time period (time slot) defined by the tag communication protocol. At step **520**, the base station transmits a carrier wave to the base station antenna The carrier wave has a steady 40 Khz amplitude modulation which is less than that required to communicate with the tags. The base station measures the 40 KHZ modulation received from the base station antenna in the time slot defined by the tag communication protocol. If the modulated signal received by the receiver **200** is steady in step **530**, the reflected modulated signal and leakage is greater than any signals received from tags, which would send an unsteady modulated signal. The base station then reduces the amplitude of the steady modulated signal in step **540** and the system returns to step **510**. If the modulated signal is not steady in step **530**, the base station checks at step **550** to see whether the modulated signal returned is steady outside the time slot defined by the tag communication protocol. If the modulated signal is unsteady when no tags are supposed to be sending signals, the unsteady signal is noise, and the receiver can not distinguish between signals sent by the tags and the noise. No tags are in reading position in the field, and the protocol is ended in step **560**. If however the modulated signal is steady outside the time slot, and unsteady in the time slot, one or more tags in the field are sending signals. These signals are stronger than the steady modulated signals received from the reflected steadily modulated carrier wave. If a single tag is in the field, and can be read at step **570**, the single tag is read and instructed to shut off, at step **590**, and the system is returned to step **540** to reduce the steady modulation and return to the beginning step **510** to try to find tags with less signal strength. If more than one tag is in the field and the tag signals interfere with each other so that they can not be read at step **570**, a multiple tag reading protocol is instituted in order to read the multiple tags at step **580**. The tags are read using the multiple tag reading protocol, and ordered to shut down, and the system is returned to step **540** to reduce the steady modulation and return to the beginning step **510** to try to find the group of tags with less signal strength than the first group.

Step **550** is preferably taken after step **530**, but step **550** may optionally be taken between steps **570** and **580** or after step **580** if no tags are read by the multiple tag reading procedure.

The most preferred embodiment of the invention uses a protocol in which the tags are commanded to return an

identification signal in a particular time slot, but the same invention may be used where the tags are commanded to return information in any defined time periods.

While the preferred embodiment uses the naturally occurring reflections from the base station antenna **185** and leakage from the hybrid **170** to introduce the noise floor signal into the receiver **200**, many other means of introducing this signal to the receiver are possible to one skilled in the art. As an example, the steady 40 Khz modulation could be summed with the signals from the I/Q demodulator coming on lines **310** and **410**, or indeed a specially constructed device analogous to a two input I/Q demodulator could be constructed to accept the steady 40 Khz comparison signal from an outside source.

Additional embodiments of the invention include further subdividing the groups selected by the above method on the basis of the phase and/or polarization of the signals returned to the base station, as well as other physical or software group selection criteria.

A preferred embodiment of the invention is to select tags on the basis of the returned polarization of the signals. In the embodiment shown in FIG. **2**, groups of tags with antennas which return a linear polarization which is polarized more parallel to one or the other of the two dipole antennas **185** or **185'** sketched in FIG. **2** are selected. Returned signals from the two antennas are processed in parallel by two sets of receiver circuitry like that shown in FIG. **4**. The tags are interrogated by transmitting the modulated carrier signal from first one antenna **185**, then the other antenna **185'**, and four channels of signals (the I and Q channels received from each antenna) may be processed in parallel or in sequential fashion. This set up would select the tags into 8 groups, which of course may be further selected and grouped on the basis of the received signal strength or any other physical or software attribute.

FIG. **6** depicts a flow chart **600** of the preferred method of selecting groups of tags on the basis of the polarization of the signals returned to the base station. As an illustrative example, a base station comprising 2 antennas which are sensitive to different polarizations, such as depicted in FIG. **2**, is chosen. However, the number of antennas and whether the polarization is linear, circular, or some combination of the polarizations may be chosen at will by one skilled in the art. Step **610** uses antenna **185** to send a signal to the tags instructing the tags to return a signal in the time slot determined by the communication protocol. The antenna **185** is then used to listen for signals from the tags in the time slot where the tags return signals in step **620**. Signals retuning from antenna **185** are analysed in step **630** to see if the base station can read the signal. If the signal is returned from a single tag, the base station communicates with the single tag in step **640**, and instructs the tag to shut itself down for the remainder of the communication protocol, or until it is specifically instructed to start returning signals again. The system is then returned to step **610** to look for more tags. If the signal returned by the tags to antenna **185** can not be read, either because there are no tags in the field in a position to be read by antenna **185** or because there multiple tags trying to communicate at the same time, the system may then try to read a single tag communicating to antenna **185'** in step **650**. If a single tag is successfully read, the system reads the tag at step **640**, shuts the tag down, and returns to the beginning step **610** to try to read again the tags which may be tying to communicate to antenna **185**. Since there is now one fewer tag in the field, a tag may now be read at step **630** on antenna **185**. If a single tag can not be read in step **650**, a multiple tag in the field reading procedure is

instituted in step **660**. Steps **630** and **650** may be taken either sequentially or simultaneously, if two receivers are connected to the two antennas. If tags are read using one antenna in step **660**, the system decides in step **670** to communicate with the tags and turn them off and the system returns to step **610** to try to read a single or multiple tag from the other antenna If the multiple tag reading procedure does not read any tags from either antenna in stop **660**, the system may switch transmitting antennas in step **680**, so that the commands and carrier wave are transmitted to antenna **185'** instead of antenna **185**. The method **600** of the invention can then be used to identify and select other groups not found in the first application of method **600**. Alternatively, the system may switch transmitting antennas between steps **650** and **660** to try to find, communicate with, and shut off single tags.

Another antenna perpendicular to the two antennas shown in FIG. **2**, which is placed remotely from the base station as shown in FIG. **3** allows all combinations of linear polarized backscattering to be discriminated and allows the selecting of groups based on all polarizations of the received signal.

The three antennas **185**, **185'**, and **185"** shown in FIG. **3** allow many more groups to be selected on the basis of phase information. A possibly different group responds in the I and Q channels of the receiver of each antenna, and the groups may be different depending on which antenna or combination of antennas sends the carrier signal to the tags. Such group selection markedly cuts down the time needed to interrogate many tags in the field.

Base station antennas and tag antennas sensitive to circular and other polarizations are also known in the art, and these also may be used by one skilled in the art in an analogous way to that shown in FIGS. **1**, **2**, and **3** and described above.

An additional preferred embodiment of the invention is to use the information on the I and Q channels to select tags into groups on the basis of the phase of the returned signal which is dependent on the distance of the tags from the base station. As a tag is moved away from the base station, the carrier signal from the tag received at the base station changes from being in phase with the transmitted signal to being 90 degrees out of phase to being 180 degrees out of phase as the tag is moved one quarter of a wavelength of the RF EM field. The amplitude in the I channel and the Q channel changes accordingly, for example from a 1 in the I channel and a 0 in the Q channel, to a 0 in the I channel and a 1 in the Q channel, to a −1 in the I channel and 0 in the Q channel respectively. Thus, selecting the signals received from the tags on the I channel alone selects a group of tags for communication, while selecting the signals received from the tags on the Q channel selects a different group of tags which are at different distances from the base station antenna. Both the I and the Q channels may be used simultaneously or sequentially to communicate with the two different groups of tags. It is possible that some tags may be in both groups at the same time. As long as there are some tags in one group and not in the other, the selecting of the groups speeds up the tag communication protocol.

FIG. **7** gives a flow chart of a preferred method **700** of selecting groups of tags by the phase of the signal returned to the base station. A signal **710** is sent from the base station to the tags instructing the tags to return modulated signals to the base station in the time slot designated for tag response. In this time period, a steady carrier wave having a defined phase is transmitted **720** from the base station antenna. If a single tag can be read on the receiver I channel **730**, the tag is instructed to shut itself off in step **740** and the system returns to step **710**. If a single tag can not be read on the I channel in step **730**, the system tries to read a single tag in the Q channel in step **750**. If a single tag can be read step **750**, the tag is instructed to shut itself off in step **740**, and the system returns to the beginning **710** to try to pick up a single tag in the I channel. If single tags can not be read in either the I channel or the Q channel, the system decides in step **750** to institute the multiple tag in field reading procedure **760**. If tags are identified in either I or Q channels in step **760**, the system may shut the identified tags off and return to step **710** to try to find single tags grouped in the other channel.

While the above method **700** has steps **730** and **750** proceeding sequentially, it is well within the scope of the invention that steps **730** and **750** may also be carried out simultaneously. If a single tag is read on either the I channel or the Q channel, the system returns to step **710**. If no single tags are read on steps **730** and **750**, the system proceeds to step **760**. In step **760**, if tags are identified and shut off, the system may at any time return to step **710** to carry out the simpler subgrouping.

With the addition of an optional phase shifting element **139**, signals from a particular tag are brought entirely into the I channel or the Q channel. The tags may then be sorted into many more groups than the two groups defined by the I and Q channels as explained above. If only one channel of information, for example the I channel, is used, changing the phase shifting element **139** to give a series of different phase delays may sort the tags into more groups. The computer section **50** may end the phase shift element **135** instructions over line **157** to shift phase by, for example 0, 30, 60, and 90 degrees which would select four different groups of tags for communication. Using both the I and Q channels, and 3 phase shifts of 0, 30, and 60 degrees gives 6 groups as another example.

If the carrier signal frequency sent out from the base station is changed, a particular tag will be a different number of quarter wavelengths from the base station and the signal will be distributed in a different way between the I and Q channels of the base station receiver. A preferred embodiment of the present invention is to select different groups of tags according to the response of the tag to such a frequency shift of the base station. FIG. **8** gives a flow chart for the method **800** of selecting groups of tags on the basis of the response of the tag to the frequency of the carrier signal sent out from the base station. In step **810**, the base station sends out a carrier wave having a first frequency f_1. In step **820**, the base station instructs the tags to return signals. The signal returning to the base station is analyzed in a single channel of the receiver in step **830**. If the signal can be read, the tag is communicated with and turned off in step **840** and the system returns to step **820** to find single tags which may have less received signal strength than the tag found in the previous cycle. If no tag is found in step **830**, the system then changes the carrier frequency sent out from the base station in step **850** to a frequency f_2, and then sends signals to the tags to return signals in step **860**. If a single tag can be read in step **870**, the tag is communicated with and shut off in step **880**, and the system returned to step **860**. If no tags are found in step **870**, the system checks to see if any tags have been found in previous cycles through step **870**, and if so the system is returned to the beginning step **810** to search the first frequency again If no tags have been found in previous cycles, the system goes to the multiple tag in the field search procedure **890**. While two frequencies are used in this example, the method is not limited to the use of just two

frequencies, and many more could be used. Use of any plurality of frequencies which shift the relative phase of the returned signal is contemplated by the inventors.

A further embodiment of the invention is to select the tags into groups on the basis of the frequency response of the tags. Tags responsive to different carrier frequencies are interrogated, and the base station is programmed to shift from one frequency to the next to select and interrogate these different groups of tags in a sequential fashion. Tags may be grouped into tags which respond to 900 MHZ, and tags which respond to 2.4 MHZ, as an example.

A further embodiment of the invention is to select the tags into groups on the basis of the response of the tags to the RF power transmitted from the base station. The method of the embodiment is to send a low power to the set of tags, and communicate with the set of tags which respond to the low power, then turn the tags which responded to the low power off. Next, the RF power transmitted from the base station is raised, and tags in a group which are further away than the first group respond, and are in turn communicated with and turned off. The process may be repeated until all tags in communication range of the base station with the maximum power allowed have finished the communication protocol.

Tags which themselves return different carrier frequencies than the base station carrier frequency are known in the art. A further embodiment of the invention is to select groups of such tags on the basis of the different measured carrier frequencies. The base station is programmed to receive the different tag carrier frequencies, either simultaneously or sequentially and to interrogate each group of tags. The different carrier frequencies known in the art are often the harmonics of the base station carrier frequency. However, the invention is not limited to the particular carrier frequency returned by the tags to the base station. If the tags can be selected into at least two groups, the communication protocol is speeded up.

FIG. **9** is a flow chart of a method of grouping the tags on the basis of the carrier frequency of the tags. The receiver is set to receive a carrier signal of frequency f_1 in step **910**. Step **920** instructs the tags to return signals. If a single tag is read in step **930**, the system instructs the tag in step **940** to turn off and return to step **920**. If no tag can be read in step **930**, the receiver frequency is changed in step **950** to f_2, and the tags are instructed in step **960** to return signals. If a single tag can be read in step **970**, the tag is communicated with and shut off in step **980**. If a single tag can not be read in step **970**, the multiple tag reading protocol is instituted. While two frequencies are used in this example, many more frequencies could also be used.

The carrier frequencies emitted by the tags and received by the base station may be apparently shifted from the base station carrier frequency by the Doppler shift due to the relative motion of the tags and the base station A further embodiment of the invention is to select groups of tags according to the Doppler shift of the carrier frequency sent by the tags and received by the base station. As an example, two groups of tags, those with relative motion of the tags towards the base station, and those with relative motion away from the base station, are selected for the communication protocol. This group selection is particularly valuable for a base station communicating with tags on one side of a doorway, for example, to measure whether the tags are carried into or out of a room.

Tags may return different modulation frequencies. A further embodiment of the invention is to select groups of tags on the basis of the modulation frequency of the returned tag signal. The base station is programmed to interrogate each group of tags either simultaneously or sequentially.

The invention is not limited to the above examples. The selection of groups of tags from a set of tags on the basis of any physically measured characteristics or attributes of the returned signal from the tags in response to any physical characteristic or attribute of the signal sent from the base station is well within the scope of the invention, as is the combination of the selection of groups on the basis of both physically measured characteristics and information contained on the tags.

We claim:

1. A method for communicating between a base station and a set of radio frequency RF transponders (Tags) comprising:

defining a plurality of RF tags into different groups according to a physical wave characteristic of the electromagnetic wave energy received from the RF tags, and

communicating with the tags in each defined group.

2. A method as in claim **1** wherein at least one defining wave characteristic is the wave amplitude.

3. The method of claim **1** wherein at least one defining physical wave characteristic is the wave frequency.

4. The method of claim **1** wherein at least one defining physical wave characteristic is the polarization of the signal.

5. The method of claim **1** wherein at least one defining physical wave characteristic is the phase shift of a return signal.

6. The method of claim **1** wherein at least one defining physical wave characteristic is the strength of tie signal.

7. The method of claim **1** wherein at least one defining physical wave characteristic is the amplitude modulation of the signal.

8. The method of claim **1** wherein at least one defining physical wave characteristic is the wavelength of the signal.

9. An RF tag base station comprising

a computer

a transmitter

a receiver, and

at least one antenna,

wherein the RF tag base station communicates with a plurality of RF tags by:

interrogating the RF tags with electromagnetic energy,

grouping the RF tags according to a physical characteristic of their responsive electromagnetic signals, and

reading the RF tags in each group.

10. A base station as in claim **9** wherein RF tags are grouped according to the wave amplitudes of their respective return signals.

11. A base station as in claim **9** wherein RF tags are grouped according to the wave frequency of their respective return signals.

12. A base station as in claim **9** wherein RF tags are grouped according to the polarization of their respective return signals.

13. A base station as in claim **9** wherein RF tags are grouped according to the phase shift of their respective return signals.

14. A base station as in claim **9** wherein RF tags are grouped according to the strength of their respective return signals.

15. A base station as in claim **9** wherein RF tags are grouped according to the amplitude modulation of their respective return signals.

16. A base station as in claim 9 wherein RF tags are grouped according to the frequency modulation of their respective return signals.

17. A base station as in claim 9 wherein RF tags are grouped according to the wavelength of their respective return signals.

18. An RF tag unit reading unit comprising:

a computer;

a transmitter;

a receiver; and

at least one antenna;

wherein the RF tag reading unit communicates with a plurality of RF tags by:

interrogating the RF tags with electromagnetic energy;

grouping the RF tags according to a physical characteristic of their responsive electromagnetic signals, and

reading the RF tags in each group.

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